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Scottish Oyster Investigations 1946-1958

By R. H. MILLAR, Ph.D., F.R.S.E.

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Scottish Oyster Investigations 1946 - 1958

By R. H. MILLAR, Ph.D., F.R.S.E.
Marine Station, Millport

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Scottish Oyster Investigations, 1946-1958

INTRODUCTION

The European flat oyster, *Ostrea edulis* L., is a native of Scottish waters. Its presence has been known m prehistoric times, when it was commonly gathered and eaten by man in the food-gathering stages society. Within historic times the occurrence of oysters round the Scottish coasts has been noted on ıny occasions and their former abundance is fairly well documented.

In addition to the unorganised gathering of shellfish from the shore there developed profitable nmercial fisheries which generally exploited shallow, coastal waters. However, a growing shortage of sters was already causing alarm by the middle of the 19th century and since that time the decline has ıtinued. Within the past few years the single remaining Scottish oyster fishery has become so un-ɔfitable that it is no longer worked.

In view of this situation the Scottish Marine Biological Association has investigated ways of reviving mer fisheries and starting new ones. At first the effort was concentrated on the coastal crofting areas, ere small fisheries would be of most economic importance, but as the work developed other places re included. Extensive field surveys were followed by experiments to test the growth, fattening and eeding of oysters. The initial work by Dr. S. M. Marshall and Dr. A. P. Orr has been described in the ports of the Scottish Marine Biological Association for 1941-47. The present report deals with the veys and experiments carried out from 1946 to 1958.

Many people have helped in various ways, and acknowledgment is made in the appropriate sections. anks are due to Dr. H. A. Cole and to Professor C. M. Yonge for their interest and advice, to the ɔpers and crews of the Association's research vessels *Calanus* and *Mizpah*, and to Miss S. I. Morris technical assistance.

THE OCCURRENCE OF OYSTERS IN SCOTTISH WATERS

ehistoric Evidence of Oysters

The frequent occurrence of oyster remains in large shell mounds and in kitchen middens, covering eriod from the Stone Ages to the Roman occupation, indicates how common the species must have en and how frequently it was used as food (Table I).

Some of these records are of special interest. The shells found near Gullane, although few, have been ed to the Neolithic, and form the earliest evidence of oysters being taken from the beds in the Firth Forth which later were commercially exploited. The extent of these beds in the Mesolithic is suggested a mound of shells, mainly of *O. edulis*, containing 6-7 million valves, at Polmonthill, Falkirk (Stevenson, 8). That the Romans also used these beds is shown by the abundance of shells in the fort at Mumrills acdonald and Curle, 1929). Another record of the prehistoric use of beds on which a fishery was er to be based comes from the shores of Loch Ryan (Gregory, Ritchie, Kennedy and Leitch, 1930).

It is evident from Fig. 1 that the prehistoric records are mainly grouped round the Firth of Forth l the Moray Firth. To some extent this reflects the distribution of man, but it also reveals the presence arge oyster beds in these two areas in the remote past.

toric Evidence of the Distribution of Oysters

A long gap in the record of Scottish oysters occurs between Roman times and the Middle Ages. ongst the earliest written accounts are those by Ben (1529), who mentioned the gathering of oysters

Fig. 1 Map showing (1) sites of prehistoric use of oysters (thus: Aignish) and (2) location of former Scottis oyster fisheries (thus: ORKNEY).

TABLE I

RECORDS OF PREHISTORIC USE OF OYSTERS

Place	Details	Reference
llswick, Shetland	Kitchen midden	Coughtrey (1873)
pa Westray, Orkney	Kitchen midden	Traill and Kirkness (1937)
usay, Orkney	Kitchen midden, up to Roman period	Callander and Grant (1934)
tle Ferry, Sutherland	Shell mound, Stone Age	Tait (1871)
gg, Easter Ross	Kitchen midden	Duns (1887)
gnish, Lewis	Iron Age	Curwen (1939)
quhart, Moray	Kitchen midden	Morrison (1873)
lbin, Moray	Kitchen midden, Bronze Age	Callander (1911)
hkeith, Fife	Kitchen midden	Grieve (1873)
llane, East Lothian	Neolithic kitchen midden	Curle (1908)
	Kitchen midden	Younger (1936)
eravon, Stirlingshire	Shell mound, pre-historic and Roman	Grieve (1873)
monthill, Stirlingshire	Mesolithic shellmound and kitchen midden	Stevenson (1948)
mrills, West Lothian	Roman fort	Macdonald and Curle (1929)
rth Berwick, East Lothian	Kitchen midden	Richardson (1900)
donan, Argyll	Shell mound	Fairhurst (1939)
rsewall House, Wigtown	Kitchen midden	Gregory, Ritchie, Kennedy and Leitch (1930)

om the Bay of Firth in Orkney, and Mackaile (in Barry, 1805) who described oysters being taken om Deer Sound, Orkney. Both places later supported fisheries. During the 16th century Hollinshead 805) included a contemporary account by Boece who mentioned the abundance of oysters in Loch van, Luce Bay, and the Firth of Forth. Wallace (1700) referred to the large size of oysters in Orkney, here few dredges were used, but where oysters were collected by hand at low water. The large size of e native oysters in the Bay of Firth was also noted by Neill (1806) who pointed out that the rough ture of the sea bed in these waters prevented the use of dredges. Barry (1805) also mentioned the oyster ds of the Bay of Firth and Deer Sound and suggested the use of some elementary methods of culture. he importance of oyster fishing in Orkney was recorded by Teignmouth (1836).

The excellence of Shetland oysters was mentioned in a letter dated 1744 quoted by Gifford (1879). hese oysters were also recorded by Neill (1806) who stated that they were common in Basta Voe, by lmonston (1809), and in the New Statistical Account (Gordon, 1845), where Fetlar, Yell and the tricts of Northmaven, Aithsting, and Sandsting are specially mentioned.

Martin (1703) and the Old (Sinclair, 1791-9) and the New (Gordon, 1845) Statistical Accounts of otland are the sources of most of the information on pp. 7 and 8.

Oysters were present in Lewis, in Harris, where they were said to be "very abundant", in South st (Loch Skiport), and in North Uist where they were "in good quantity" and "so big that they are t into four pieces" before being eaten. In Skye they occurred in the Sound of Scalpay where a spring e uncovered "fifteen, sometimes twenty, horse load of them on the sands", "of a superior quality but small size". Oysters were present in Mull in Loch Scridain, Loch na Keal, Loch Spelve and at Ulva. Jura most of the coast is unsuitable, but Loch Tarbert formerly had "great quantities of lobsters, sters and craw-fish" and much more recently Fullarton (1891) found a few oysters there. In Islay ere is a record for the parish of Kilchoman. Sutherland had oysters in the parishes of Durness and Eddra-illis, and, according to Young (1889), in Lochs Eriboll, Inchard, Laxford, Glendhu, and Glencoul. Ross and Cromarty there were beds in Gairloch and Loch Ewe (Dixon, 1886), in Little Loch Broom oung, 1889), and in Loch Torridon (Buchanan, 1793). Written records are lacking for the western ast of Inverness-shire, although oysters do occur there.

Argyll yields many records. Oysters were present in Morven. In Loch Creran there were beds, scribed in the New Statistical Account as having "no great numbers of oysters", but marked on the lmiralty Chart (No. 2814b) and evidently productive in the second half of the 19th century (Young, 92). Oysters existed in Lochs Feochan and Melfort and were present in small numbers in Loch Caolis-rt. They were common on the east and west shores of Loch Sween and abundant in Loch Craignish. West Loch Tarbert they were noted for their great size and good quality and Smith (1813) recorded

large deposits of dead shells indicating the former abundance of the species. The fishery which wa developed here and the fate of the stock are described on p. 11.

Within the Clyde area there were beds at Inveraray. According to a letter from James Campbe of Inverneill to the Duke of Argyll, dated 1771, young oysters were plentiful on the shore there (persona communication from J. L. Campbell of Canna), but it is possible, as in other references to "young oysters" that the false oyster *Anomia ephippium* L. has been mistaken for the true oyster. On the Oitir, or Otte Spit, a tidal bank in Loch Fyne, there existed "an excellent oyster bed, whence are obtained considerabl quantities of oysters of a superior quality, which are known by the name of Otter oysters". Other part of the Clyde area had apparently but few oysters, although there are records from Loch Goil and fro the shores of Dunoon and Kilmun parishes.

Most of the Ayrshire coast consists of exposed rocky and sandy shores unsuitable for the specie In Wigtownshire natural beds have long been known in Luce Bay and especially in Loch Ryan, whe the abundance and excellent flavour of the oysters has been noted. In Kirkcudbrightshire there ar records for the parishes of Kirkcudbright and Borgue, "considerable numbers" of oysters having bee noted on the shore near Kirkcudbright.

The eastern seaboard of Scotland is much less indented and, therefore, offers fewer of the sheltere sites favoured by oysters, but a few extensive firths provide large areas of shallow water with a suitabl sea bed on which considerable populations of oysters could, and once did, flourish. Young (1889) foun that the presence of oyster beds in the Moray Firth, especially near Avoch, was well known locally, bu the largest oyster beds in Scotland were located in the Firth of Forth. The use of these beds in prehistor and Roman times was extensive and in 1329 the first charter was issued granting the rights of oyste fishing to the City of Edinburgh. Since then many documents have dealt with the fishery. A more detaile account of the events leading to the final extinction of the beds will be found on pp. 10 and 11.

Present Distribution of Oysters

The foregoing review of references to the past occurrence of the species on the Scottish coasts leav no doubt that it was common in many places and even abundant in some favoured places. Oysters a now far less common but it is difficult to make an accurate comparison between the distribution no and in the recent past. The position is complicated by the numerous scattered and often unrecorde introductions of oysters from English, French and Dutch sources. Therefore, although oysters can sti be found in a number of places, it is often uncertain whether they are native stock, the remnant of som importation or the result of crossings between stocks of different origins.

Personal records have been supplemented by a number of correspondents who have kind sent information on recent finds of living oysters on many parts of the Scottish coast. It is unnecessary t give details of these records and sufficient to note that oysters are known to exist, or to have done s within recent years, in the islands of Orkney, Lewis, North Uist, Skye and Mull and on various par of the mainland coasts of Sutherland, Ross and Cromarty, Inverness, Argyll and Wigtown. In some these places, where, within living memory, oysters were relatively common, they are now scarce, and i other places they have disappeared altogether. The reasons for these changes will be discussed on p. 14

HISTORY OF THE SCOTTISH OYSTER FISHERIES

The main sources of information regarding commercial fisheries are the official returns of landin published first in the Annual Reports of the Fishery Board for Scotland and later in the Scottish S Fisheries Statistical Tables. It is often difficult to get information for dates before these publicatio started except for such important fisheries as that in the Firth of Forth. Fig. 1 shows the main fisheri which have existed in Scottish waters.

ch Ryan

A charter of 1701, granted by William III, conferred on the Wallace family of Cairn Ryan the oyster ing rights in Loch Ryan. The early history is obscure, but the fishery does not seem to have been hly organised at the time of the Old Statistical Account (Sinclair, 1791-99), according to which ters "might be got in great quantities would people drag for them". No mention was made of a fishery the New Statistical Account, although the quality and quantity of local oysters were noted. That a ery existed early in the 19th century is shown by a statement, dated 1876, by Lt. Col. W. T. F. A. llace, affirming that the fishery had been under the personal supervision of members of the family more than 60 years. The great demand for young oysters in the 60's and 70's of last century led to sale of young stock and at about this time, according to Young (1888), the fishing on the productive nk known as the Scar was relinquished by Sir William Wallace and opened to the public, whereupon at quantities of oysters of all sizes were removed to the detriment of the beds. The severe strain imposed the beds at this time may be judged by the fact that about 30 boats were dredging for oysters. Stricter ulations were imposed and it is probably owing to the vigilance of successive owners over a long iod, in spite of inducements to sell under-sized oysters, that the local stock survived. Figures of catches ore 1884 are not available, because individual fishermen paid a lordship for permission to dredge d sold their catch independently of the owner of the fishery.

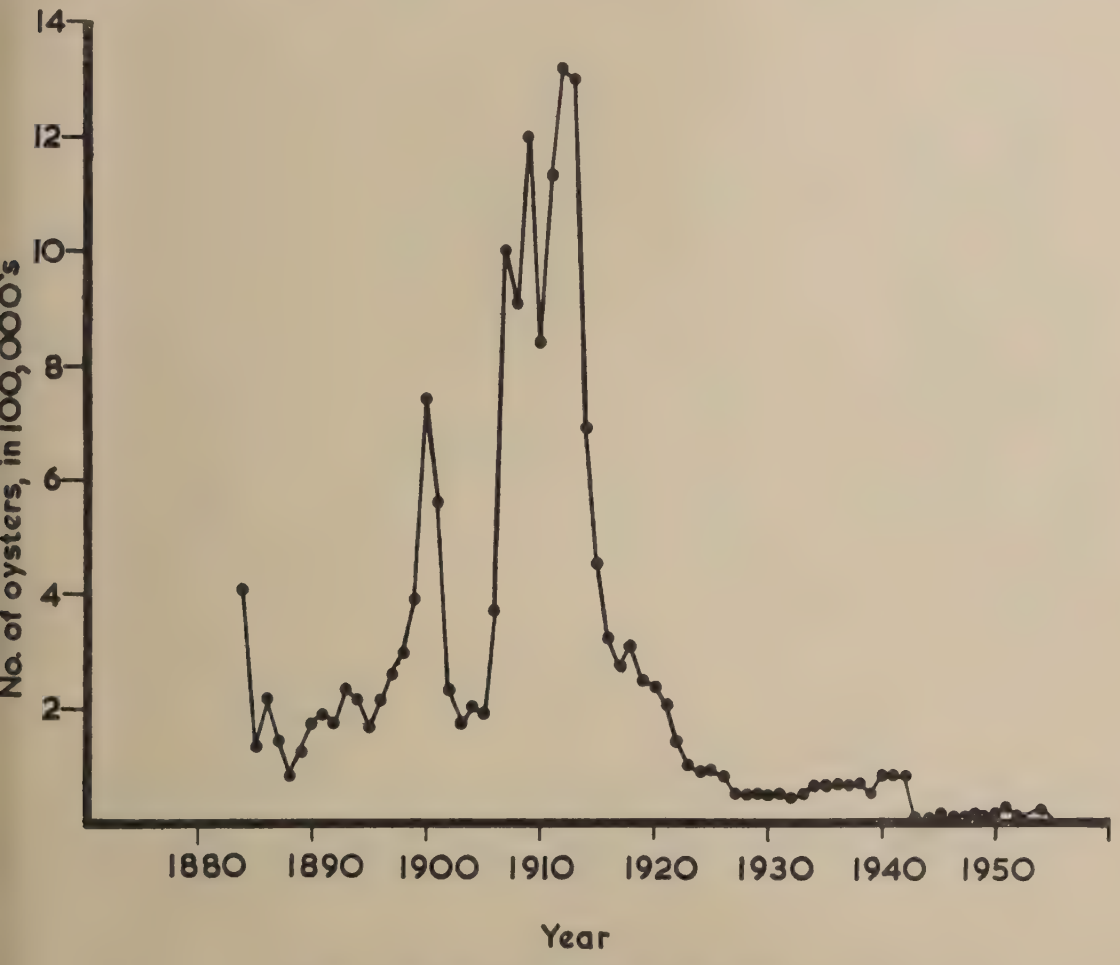


Fig. 2 Landings of oysters, Loch Ryan fishery.

Fig. 2 shows the catches from Loch Ryan recorded at Ballantrae. After a period of fairly stead fishing from 1884 to about 1906, landings for each of seven successive seasons were three to four tim their former size. This rate of fishing was apparently too great for the stock and the returns steadil declined from 1914 until 1954 when the fishery became uneconomic. The picture of this fishery is com plicated by a number of importations from Essex, France and Holland that were made from time time, details of which were apparently not recorded.

The present condition of the beds was investigated and an account of the findings is given on pag 16-21. The Scottish Marine Biological Association is at present engaged in a programme of work in Loc Ryan with the object of bringing the beds again to a thriving and commercially profitable condition.

Firth of Forth

The history of the oyster fishery in the Firth of Forth seems to provide a classic example of the proce of overfishing, starting with a very abundant stock and ending with its complete extinction. An accou of the history of these beds up to 1895 was given by Fulton (1896) and the present account is a short survey, which brings the records up to date. Fig. 3 shows the recorded landings of oysters, the ear records and estimates having been taken from the report of a Select Committee on Oyster Fisheri (Anon., 1877) and from Fulton (1896).

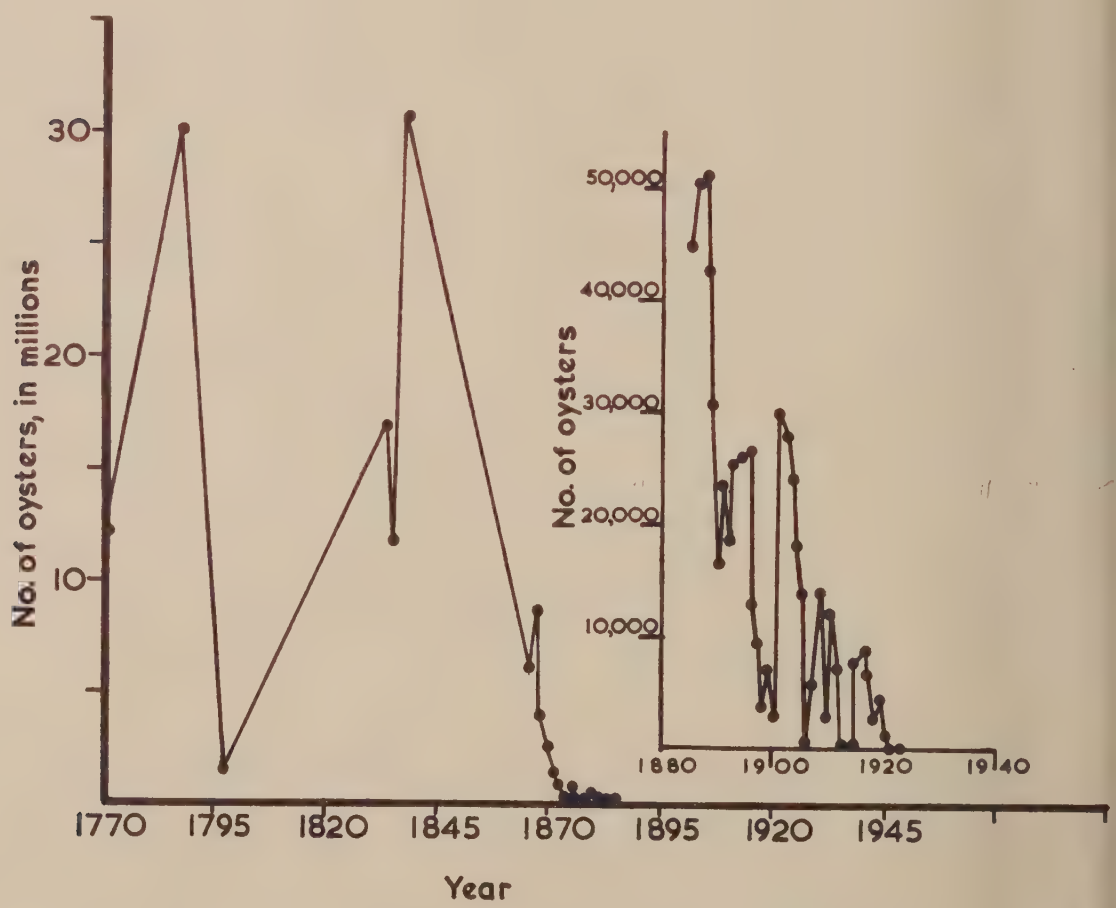


Fig. 3 Landings of oysters, Firth of Forth fishery. Inset shows in detail the final decline of the fishery.

The great area of the beds, extending for about eight miles eastwards and eight miles westwards of ith and across most of the width of the firth, represented a vast natural population of oysters. So long the methods of fishing were relatively inefficient and the number of boats working was small, little pression was made on the stock. During the last quarter of the 18th century, however, and particularly the period roughly extending from 1770 to 1795, the intensity of fishing increased. At this time great antities of oysters, including young ones, were sent to the English and Dutch beds, leading to a serious cline in the yield about the turn of the century. Restrictions imposed in 1814 by the City of Edinburgh l to a marked revival of the beds during the following ten years, and when fishing was resumed on a ger scale the annual catch again became high. But once again overfishing set in and for over 40 years protective measures failed to limit the catches to a level comparable with the natural productivity of beds. Consequently the period 1865-1875 saw a sharp fall in landings, which marked the start of final decline of the beds. With small fluctuations the yield fell steadily until about 1920 when the hery ceased. Since that year small numbers of oysters have been found along the southern shores of the th until as recently as 1948. The evidence of overfishing appears to be conclusive and Fulton (1896) htly stated that "there can, indeed, be no doubt that the true cause of the exhaustion of the Forth ds was the long course of improvident and reckless fishing to which they were subjected".

The present condition of the beds is described on pp. 14-16.

est Loch Tarbert

Towards the end of the 18th century oysters were already being sent from West Loch Tarbert to ampbeltown and Glasgow (Sinclair, 1791-9). The first official records showed that a fishery existed in 84, and Messrs Hay and Company were granted a Fishery Order in 1888. Oysters had become relatively arce by 1886 (Young, 1888), and about this time the lessees introduced about 400,000 oysters. These ere taken, at least partly, from areas of the west coast including Loch Sween (Young, 1888) and, cording to Captain R. Hay (personal communication), from the Hebrides. Captain Hay stated that ench oysters were also laid. Fullarton (1891) reported that the beds contained about a million oysters 1890. The heaviest landings were made from 1889 to 1900 and this excessive exploitation was followed a gradual decline (Fig. 4). From 1922 to 1938 the returns were small and diminishing and none was corded after 1938. Within recent years few oysters have been found anywhere in the loch.

During the period when the fishery flourished the lessees used some cultural methods. For example, small breeding pond was built at Rhu, stocked with oysters and provided with tiles and branches of ees for the collection of spat. According to Captain Hay this pond had some success, with the spat ustered "like cherries" on the branches. Efforts were also made to reduce the numbers of starfish by e use of baited traps. The traps, which were laid on the bottom and buoyed, consisted of a metal ring pporting netting with bait in the centre; about six traps were used on the main beds at Rhu. In spite these cultural methods the drain of oysters exceeded recruitment by spat-fall and by laying, and the tinction of the fishery followed.

Extensive experiments in West Loch Tarbert formed part of the research programme and are ported on pp. 53-68.

rkney

Oyster fishing was practised in Orkney long before fishery statistics were kept. At first, oysters were thered by hand at low water and collected from submerged reefs by tongs manipulated from a boat ith the aid of a glass-bottomed viewing box. Mackaile (Barry, 1805) referred to oysters being taken at eer Sound and near the island of Damsay with "spits of iron", and the use of tongs was referred to by eill (1806). Some dredges were presumably in use, however, as early as 1700, when Wallace noted how ncommon this method of fishing was in Orkney. Both tongs and dredges have been used within living emory.

The production of oysters was never large in Orkney, although two considerable areas, the Bay of irth and Deer Sound, were fished. In each of these places, however, much of the sea bed is unsuited to

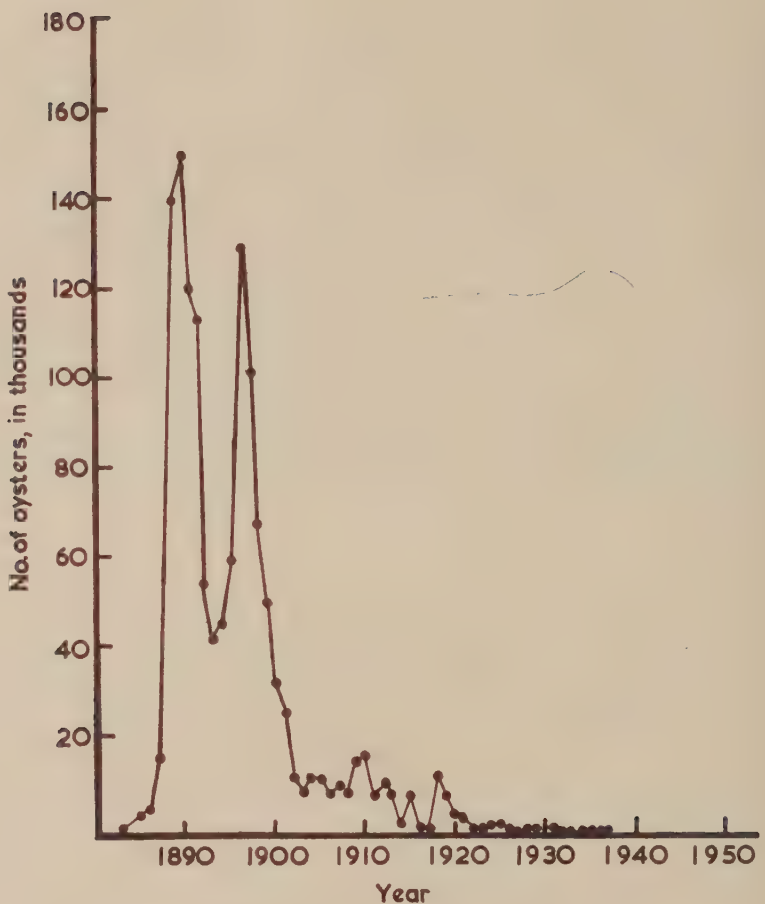


Fig. 4 Landings of oysters, West Loch Tarbert fishery.

dredging and the use of tongs restricts the numbers of oysters collected. The greatest annual output wa about 15,000, in the year 1915.

Efforts have been made to revive the fishery. In 1908 a syndicate was formed and protection wa granted by the Secretary of State in 1910. The area included in the Bay of Firth Oyster Fishery amounte to 4,500 acres. Work on cleaning the beds was begun in 1912, large quantities of culch were laid and abou 800,000 young oysters introduced from England. Further large layings were made and more culc added, but during the period 1914-1918 work was curtailed, and when the beds were examined afte the war it was found that most of the oysters had died. Danish oysters were subsequently laid, but th stock perished and the syndicate was wound up in 1937.

It is difficult now to find the causes of failure. According to local information many oysters, whic arrived in poor condition after a long journey, died in their first winter on the beds, and the soft mu on which they were laid may also have contributed to their failure. Even under good conditions oyste from English beds are probably unable to breed freely at the low temperatures of Orkney waters. N subsequent efforts have been made to revive the fishery.

Shetland

Shetland can hardly be said to have supported a regular oyster fishery. Landings were irregula and for long periods few or no oysters were taken. The relatively heavy catches from 1931-1933 seem t have exhausted the natural beds.

YE

Oysters have been gathered and sold from various parts of Skye, but only the Greshornish Fishery rder of 1872 indicated a serious attempt to organise a fishery. According to evidence provided for the lect Committee on Oyster Fisheries (Anon., 1877), the beds in Loch Greshornish had been depleted the public long before 1872 and protection, following the issue of the Fishery Order of 1872, had led a gradual increase in the numbers of oysters. It is difficult to discover from fishery statistics how many sters were marketed from any particular part of Skye. The combined returns from Loch Carron and ye never exceeded 2,000 oysters in a season.

JCE BAY

Luce Bay in Wigtownshire apparently supported a small fishery for a short time towards the end of e 19th century (Young, 1888), but details are not available.

IGTOWN BAY

An oyster fishery flourished here for some years. According to Young (1888) the bed was found cidentally about 1868, outside Garlieston Bay. Following this, large quantities were dredged and as any as 40 tons of oysters were sometimes despatched by steamer. I am indebted to Mr. Charles Maguire Isle of Whithorn for the following information regarding the fishery. Over 70 boats from Essex and out 30 local boats worked the beds, which existed in the mouth of Wigtown Bay on a line from the Isle Whithorn to Borness Point. In spite of regulations to prevent fishing close to the shore, intensive ploitation of these beds led to a decline in catches and the Essex boats apparently did not return after out 1880. For a few years the local boats continued to fish, but soon they too found it unprofitable. The rgest beds were in water of 12 to 14 m, on a bottom of shingle and mud. Small numbers of oysters have een found in recent times and in 1926 some were still present on the shore.

OCH SWEEN

Towards the end of the 19th century attempts were made to develop a fishery in Loch Sween and a rotective Order was granted in 1891. It is not clear from the published records whether oysters were ld, but efforts were made to cultivate them and to improve spatfalls by the use of tiles as collectors. rench oysters were introduced into Linne Mhuirich to supplement the native stock and the total stock as about 3 millions in 1895.

A field experiment in breeding was made in Linne Mhuirich as part of the present programme and reported on pages 43-48.

ROMARTY AND MORAY FIRTHS

Gordon (in Lubbock, 1863) stated that oysters could be found in small numbers in Cromarty Firth, t Cromarty, Alturlie and Avoch.

The landing of 25,000 oysters in 1884 probably marked the last phase in the depletion of the once rolific beds in the Moray Firth. The decline followed the discovery and exploitation of the beds by nglish smacks, according to Young (1888), who stated that, for several years about 1878, boats "fished ersistently until the oysters were practically exhausted".

EWIS

Landings recorded at Stornoway probably represent oysters gathered from several areas in Lewis. he records extend from 1884 to 1909, with a maximum of 20,000 in 1904. The numbers were generally uch less than this and in several years no catches were recorded.

DECLINE OF THE SCOTTISH OYSTER FISHERIES

There can be no doubt that oysters are now much scarcer than formerly round the Scottish coast Several possible reasons have been advanced to explain the decline. Environmental changes, especiall in the water temperature and in the nature of the bottom, and increased pollution have been suggested Fulton (1896) considered and rejected these as causes in the Firth of Forth. Extinction of the beds ther certainly cannot be attributed to lower sea temperatures, as neither water temperature in the easter North Atlantic (Smed, 1948) nor air temperature at Edinburgh (Lysgaard, 1948) has declined sinc the middle of the 19th century.

Mud and debris were deposited on certain parts of the Forth beds during dredging operations an as a result of the reclamation of bogs, but very large areas of the beds were apparently unaffected an have retained a substratum suitable for oysters. It is unlikely that pollution by sewage damaged thes beds, as this is not harmful in moderate quantities and in any case a certain amount of pollution ha existed for centuries in the area. The importance of industrial pollution is more difficult to assess, and th factor may have contributed to the decline of the beds near Edinburgh, but it is difficult to avoid Fulton conclusion that the environment is still suitable.

If this is true of the Firth of Forth it would seem even less likely that fundamental harmful change have occurred in the environment remote from large towns. Indeed, in the few cases where seriou efforts have been made to conserve stocks, greater settlements of young oysters and larger resultan populations of adults have followed, thus indicating that environmental conditions are still suitable.

If changes in the environmental conditions are not responsible, overfishing would appear to be th most likely explanation of the decline. It is clear from the frequent references which have appeared in th foregoing accounts of commercial fisheries, that overfishing has occurred repeatedly on most or all of th beds. This is the one factor which is well documented and which alone seems to give an adequat explanation of the widespread decline in oyster stocks. Once the stocks have been seriously reduced other factors may hasten the decline and the final extinction of local populations. As Gross and Smyt (1946) have pointed out, small oyster populations may have difficulty, for genetic reasons, in rapidl increasing to their former abundance. Moreover, many females possibly remain unfertilised where oyste are few and widely separated.

Two factors are relevant in estimating the importance of heavy fishing as the prime cause of th reduction of stocks. In the first place, oysters in many localities were apparently confined to small area with suitable conditions. Secondly, in the latter half of the 19th century the collection of oysters wa intensified, partly to supply and restock new and existing fisheries. When, for instance, a fishery wa started in West Loch Tarbert, Argyll, a widespread search was made for young oysters and considerab quantities were brought in from other parts of the west coast including the islands. There are als references to boats from Essex removing large quantities from places as far apart as the Moray Firt and Wigtown Bay.

It therefore seems likely that human predation has been the chief factor in bringing about th present situation. Oyster fisheries might be revived if stocks of suitable oysters could be built up in favou able areas. This, however, could only be achieved by the control of fishing and by the introduction cultural methods with a view to improving the growth and fattening of adult oysters and to ensurin an adequate supply of young oysters.

PRESENT CONDITION OF SOME FORMER OYSTER BEDS

Firth of Forth

The decline of the beds in the Firth of Forth led Fulton (1896) to survey most of this formerly pr ductive ground. Using commercial oyster dredges he found only 317 living oysters in 233 dredge haul each of an average duration of 10 to 12 minutes. He estimated that the population density might l

ween 7·3 and 14·6 oysters per acre, representing a total population of a quarter to half a million over whole of the old oyster grounds in the firth.

A similar but smaller survey, using Fulton's method, was made by the research vessel *Mizpah* in y, 1957. A series of 65 hauls (Fig. 5), each of 5 to 10 minutes' duration, was made so as to cover much he ground surveyed by Fulton, including those places where he had found oysters to be commonest. e gear used was a standard oyster dredge, 1·37 m (4·5 ft) wide, with rings of 6·35 cm (2·5 in.) diameter.

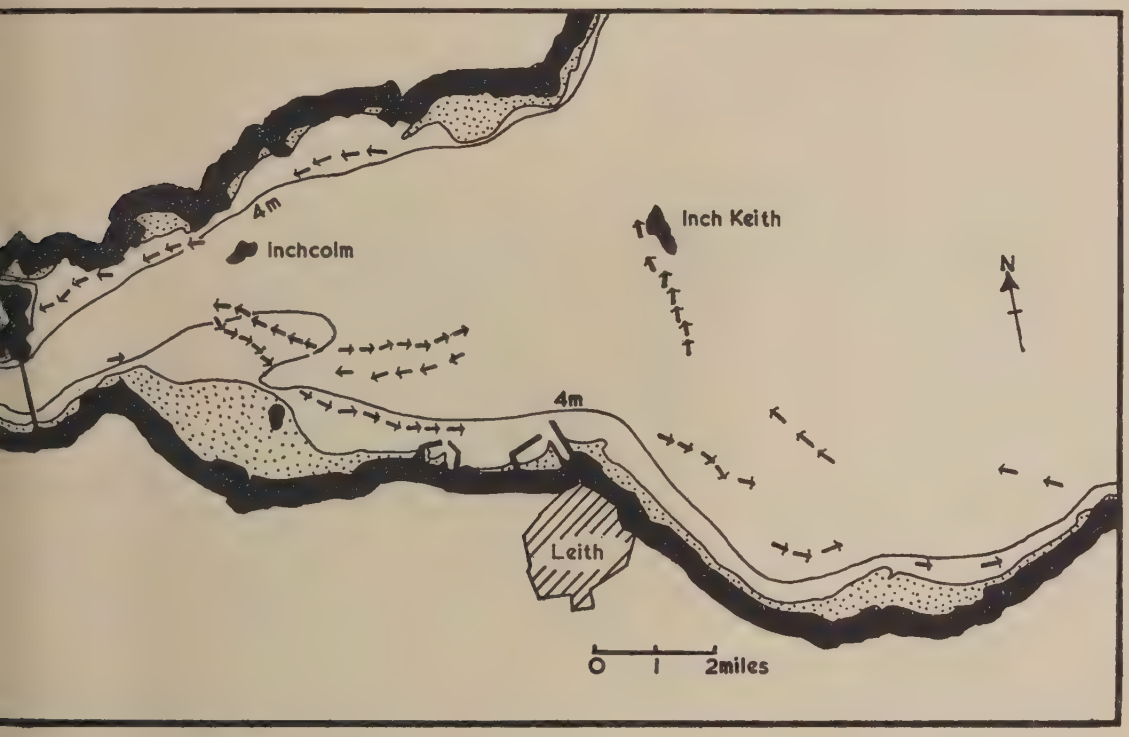


Fig. 5 Firth of Forth, showing positions of hauls in dredge survey.

Table II summarises some of the more important results obtained. The most noticeable features re the complete absence of living oysters and the presence of only one "clock", or pair of valves still ached by the ligament, indicating a recently dead oyster. There may still be a few oysters in the Firth Forth but the beds must be regarded as now virtually exhausted. Other changes since Fulton's survey shown in Table III which compares the mean number of specimens of some conspicuous species per ndard 10-minute haul.

TABLE II

SOME DETAILS OF DREDGING SURVEY IN THE FIRTH OF FORTH, 8TH-10TH MAY, 1957

Total number of hauls	65
Number of hauls containing living oysters	0
Number of hauls containing dead oyster shells still in pairs	1
Number of hauls containing dead, separated oyster shells	48
Number of hauls containing *Asterias rubens*	42

TABLE III

MEAN NUMBER OF SPECIMENS OF FIVE SPECIES PER STANDARD 10-MINUTE HAUL TAKEN IN THE SURVEYS OF THE FIRTH OF FORTH IN 1895 AND 1957

	Asterias rubens	*Solaster papposus*	*Chlamys opercularis*	*Buccinum undatum*	*Modiolus modiolus*
1895	19	1·1	150	6	35
1957	12	0·06	1·6	0·8	5·4
Ratio $\frac{1895}{1957}$	1·5	18·3	94	7·5	6·5

The fact that the number per haul of every species enumerated was less in 1957 suggests that the may have been some difference in the sampling method, but this is hardly likely to account for su large reductions in the numbers of *Chlamys opercularis*. It may, therefore, be concluded that, concurren with the sharp decrease in the numbers of oysters, reductions also occurred in the populations of so other species, notably *Chlamys opercularis*. This might be thought to indicate some change in the enviro mental conditions particularly unfavourable to lamellibranchs. That such a conclusion is not justifi may be inferred from Fulton's statement that *Chlamys* had become much more abundant on the oys grounds during the 20 or 30 years preceding his survey. He suggested that as oysters decreased *Chlam* increased and spread into the areas formerly occupied by the oyster. The almost complete disappearan of the oyster has not, however, been accompanied by a continued rise in the numbers of *Chlamys*, and may be that marked changes in the population of *Chlamys* have occurred quite independently of t decline in numbers of oysters. Changes in the status of *Chlamys* do not, therefore, necessarily indica changes in the environment which might account for the decline in numbers of oysters. Nor is there a direct evidence that the substratum has become less favourable to oysters, at least over most of the be despite an apparent accumulation of mud in some places. There is still an apparently ample supply culch in the form of dead oyster shells in a sufficiently clean condition to allow the settlement of larv were they present in the water.

Following his survey of the beds Fulton (1896) recommended remedial measures, but nothing w done, and the stock was by then so thinly scattered that it was probably incapable of making a natu recovery without an adjustment of the ecological balance so as to favour the settlement and survival oysters. The density of about 7 to 15 oysters per acre, estimated by Fulton, almost certainly ensured th a substantial proportion of eggs remained unfertilized and that the population, far from even maintaini itself, would quickly decline, particularly if enemies like *Asterias* were allowed to multiply. There is n little or no stock from which recovery could be made, even if vigorous action were taken. Oysters mig be introduced from elsewhere to act as breeding stock, but this would be very costly and it would difficult to find oysters which would breed freely at the temperatures that prevail in the Firth of Fort There is, therefore, little hope that anything can be done now to revive these beds.

LOCH RYAN

The oyster beds are confined to the inner part of the loch, that is, the large basin between Stranra and The Spit. This is an area of shallow water, almost everywhere less than 5 m in depth, which sheltered from all directions except the north-west. Such conditions favour oysters, and, moreover, t smooth sea floor ensures ease of dredging. Soil analysis shows that a belt along the south-east sho from low water to a depth of about 4 m, consists of a firm, slightly muddy sand. Farther north, betwe Leffnoll Point and Cairn Ryan the bottom becomes harder and more sandy. The large central part the area, mainly with depths between 4 and 5 m, has a rather softer substratum, containing more mu

redging surveys

The first survey was made in November, 1957, by the *Mizpah*. A series of dredge hauls, each of 10 5 minutes' duration, was taken so as to cover as much as possible of the ground. The gear used was a mercial oyster dredge, 0·91 m (3 ft) wide, with rings of diameter 5·1 cm (2 in.). The positions of the s are given in Fig. 6 and a summary of the results in Table IV. All oysters were recorded, including easily visible to the naked eye.

TABLE IV

DETAILS OF DREDGING SURVEY IN LOCH RYAN, 5TH AND 6TH NOVEMBER, 1957

f	Dead oyster shells	No. of living oysters	Notes on catch and nature of bottom
	A few	0	*Laminaria* sp., *Ascidiella aspersa* (6), *Archidoris* sp. (1), hermit crabs
	A few	2	Bottom firm, *Laminaria* sp., *Chlamys* sp. (1), *A. aspersa, Solaster* sp. (1)
	A few	0	Bottom firm, *Laminaria* sp., *Anomia* sp. *A. aspersa, Dendrodoa grossularia, Portunus* sp. (several), *Cliona celata*
	A few	0	Bottom firm, *A. aspersa, D. grossularia*
	A few	0	Bottom firm, *A. aspersa, D. grossularia, Portunus* sp.
	——	—	No catch
	0	1	——
	Many	0	*Henricia sanguinolenta* (1)
	Many	4	Bottom muddy
	A few	1	Bottom muddy
	A few	2	Bottom muddy
	A few	30	*Ciona intestinalis* (2)
	0	7	*A. aspersa* (1)
	——	—	No catch
	A few	21	Bottom muddy, *A. aspersa* (several), *Metridium senile* (1)
	Many	100-200	Bottom with stones and pebbles
	A few	A few	*Aphrodite aculeata* (1)
	0	A few	——
	A few	6	——
	A few	0	*A. aspersa* (several)
	Many	37	*Buccinum undatum* (1), *C. celata* (1), *M. senile* (1), *Hyas* sp. (1)
	Many	6	*A. aspersa* (many), *H. sanguinolenta* (1)
	0	A few	Red alga
	A few	0	Red alga, *Carcinus maenas* (several)
	0	6	Bottom muddy, *Laminaria* sp., dead shells of *Turritella communis*
	0	2	Bottom muddy, *Laminaria* sp., *A. aculeata* (1), *A. aspersa*
	0	0	*Laminaria* sp.
	0	0	Bottom hard, *Laminaria* sp., *Echinus esculentus* (1)
	0	0	Bottom rocky, *Laminaria* sp., *Solaster* sp., *E. esculentus*
	Many	9	*B. undatum, A. aspersa, D. grossularia, H. sanguinolenta* (2), *Portunus* sp.
	Many	1	Dead shells of *Pecten maximus* and *Cardium* sp., *Laminaria* sp., *A. aspersa, E. esculentus* (1)
	Many	12	*A. aspersa* (many), *E. esculentus* (1)
	0		Wire rope with several hundred living oysters attached to it
	0	A few	——
	0	5	——

Another survey was made in October, 1958, to investigate more accurately the density of oysters he beds. The methods and gear were similar to those of the first survey, but on this occasion the *nus* was used, and each dredge haul was made over a distance of 600 yards (550 m), while noting, he Decca navigation system, the positions of the start and of the end of each tow. Fig. 6 shows the tions of the hauls. Results are given in Table V which records all living oysters down to those of ut one centimetre in diameter.

In the survey over a known area 537 oysters, of all sizes excluding small spat, were taken and of this l only about 85 were estimated to be large enough to breed. The area covered by the dredge was ut 11,400 sq.yd. (9,580 sq.m) and assuming that the gear worked with 30% efficiency (Shelbourne, 7) the number of oysters per acre is estimated at 760 of which only about one sixth, or 127 per acre, d possibly breed. It is evident that oysters and, in particular, large ones, are scarce. The total breeding k on the beds may be of the order of 330,000.

A breeding stock of this size would be expected to yield important quantities of spat only in an area

Fig. 6 Loch Ryan, showing positions of numbered hauls in dredge surveys. Numbers 1-35, shown in bold type, refer to the survey of 1957 and numbers 1-19, underlined, refer to the survey of 1958.

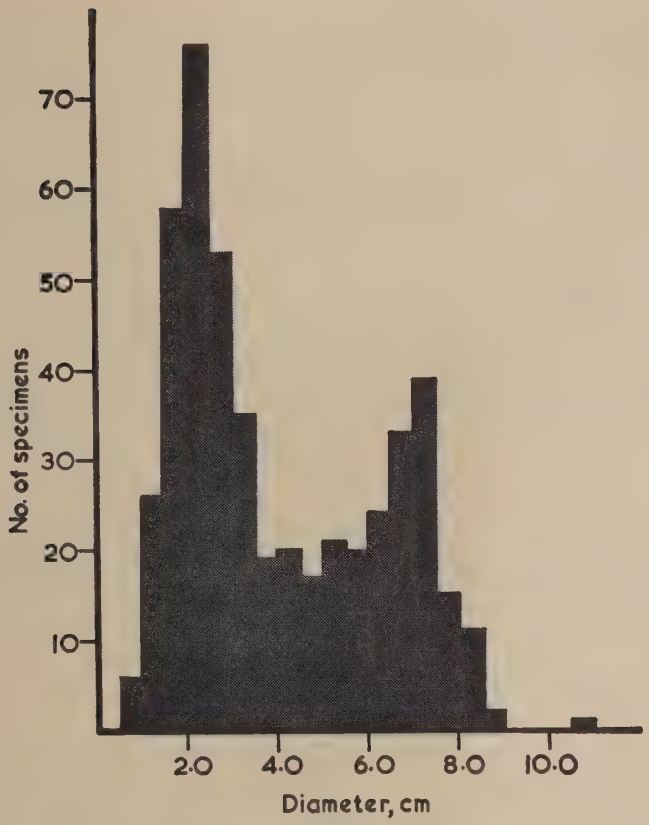


Fig. 7 Size-distribution of Loch Ryan oysters sampled in November, 1957.

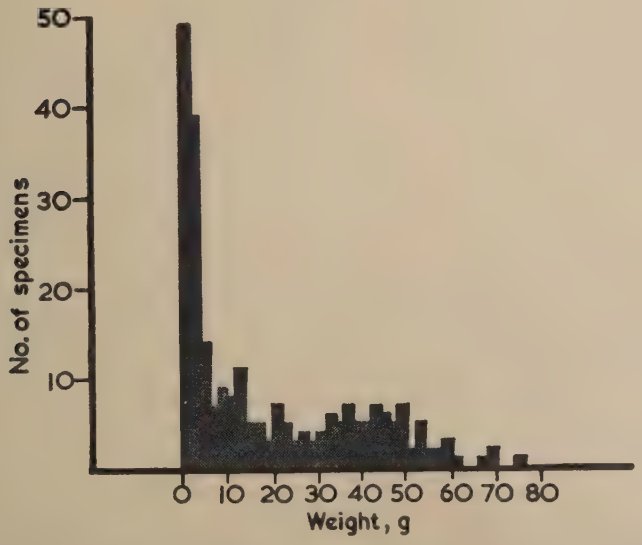


Fig. 8 Weight-distribution of Loch Ryan oysters sampled in November, 1957.

with favourable conditions. In the present case the percentage distributions of oysters by size (Fig. 7) and by weight (Fig. 8) indicate a series of spatfalls during recent years. In 1958 also, at least one spatfal occurred, in late September or early October. There is, therefore, good evidence that the area is stil very suitable for breeding.

During these two surveys only one specimen of *Asterias rubens* was taken. This is a remarkable and favourable feature of the beds, although it is possible that this starfish might invade the area in greate numbers if more oysters were present. The starfish *Henricia sanguinolenta* was taken in slightly greate numbers, but is not common; its food is unknown but may include molluscs (Mortensen, 1927). Crabs which were also taken, would constitute some danger to spat, although not at present a serious threat The only other animals on the grounds known to be of much concern to an oyster fishery are *Ascidiell aspersa,* which was quite numerous in certain places, and the boring sponge *Cliona celata.* The ascidian can foul culch or spat collectors, thus reducing spatfalls, and it can also to some extent interfere with dredging if very abundant. It is, however, common on many good oyster beds and is not generally a very serious pest. The boring sponge does not seem to be sufficiently abundant to constitute a seriou danger.

TABLE V

DETAILS OF DREDGING SURVEY IN LOCH RYAN, 30TH AND 31ST OCTOBER, 1958

No. of haul	Dead oyster shells	No. of living oysters	Notes on catch
1	0	101	
2	A few	6	*Henricia sanguinolenta* (1)
3	0	78	*Asterias rubens* (1)
4	Many	4	Brittle stars
5	A few	3	Red alga, *H. sanguinolenta* (1), *Crangon* sp. (1)
6	A few	47	
7	A few	20	*Solaster* sp. (1), *H. sanguinolenta* (1)
8	0	18	
9	A few	7	*Ascidiella aspersa* (many)
10	A few	77	*A. aspersa* (many)
11	A few	18	*Portunus* sp. (several)
12	A few	10	*A. aspersa* (several)
13	0	46	
14	0	11	*A. aspersa* (many)
15	A few	4	*A. aspersa* (several)
16	0	22	
17	0	30	
18	Many	21	*H. sanguinolenta* (1), *Portunus* sp.
19	0	11	

Under-water television survey

A survey was made in June, 1958, using the under-water television equipment (Barnes, 1953) supervised by Dr. H. Barnes and Mr. A. Randall. The object was to determine more exactly the nature of the substratum and in particular the quantity of dead shells on which oyster larvae could settle. It is difficult to judge whether shells dredged up have been bare or covered by a thin layer of deposit which would render them unavailable to settling oyster larvae, but viewing the material *in situ* overcomes this difficulty.

Two methods were adopted in the work. (1) The *Calanus* was anchored at each of a series of 5 stations, and at each station a few sample areas of the bottom were examined in detail. (2) The ship was allowed to drift for about 500 yd, with the camera a few feet off the bottom thus giving a less detailed view of a much larger area. Positions were marked accurately by means of the Decca navigation system.

The survey showed that the area of the beds can be divided into two main parts from the point o

ew of oyster ground: (1) a narrow inshore belt consisting of muddy sand with some shell, but having places much debris and a rather dense covering of algal growth which may render parts of the area nsuitable for oysters; and (2) the remaining much larger area of stiff, sandy mud with few whole shells ıt with thinly scattered fragments of broken shell mainly under one centimetre in diameter. The largest ells here were generally of *Turritella communis*. The large central area, of at least 3 square miles, is free weed except for some *Laminaria*, has a uniformly even substratum, and is apparently suitable for oysters. s main disadvantage is the serious shortage of shells to act as settlement surfaces for larvae.

Conclusions and recommendations

Loch Ryan is a favourable area, which would appear to be worthy of cultivation. Nevertheless the ds contain so few oysters of marketable size that they could not be worked at present as an economic hery. Four procedures would help to restore the prosperity of the beds. These are: (1) ensuring a riod during which no oysters of any size whatever are removed; (2) laying culch in some suitable rm to catch larger spatfalls; (3) keeping down enemies and competitors; (4) possibly adding more eeding stock, if a quick revival is wanted. Other measures could also be adopted, including harrowing e beds to uncover dead shells to act as settlement surfaces, but there is no clear evidence that large ıantities of dead shells lie under the surface. Artificial collectors could also be used, although this volves much time, expense, and labour. Furthermore, on the fishery regaining its former economic ıte, it would be necessary to ensure that it is properly regulated, that good conditions for settlement e maintained and, in particular, that enough breeding stock is always left on the beds. The measures ggested could make the Loch Ryan beds prosperous once more. Further research is in progress and ll be reported at a future date.

FIELD EXPERIMENTS ON GROWTH AND FATTENING

This part of the investigation was carried out to test the suitability of different places for growing d fattening young relaid oysters. It was also hoped that layings made under a variety of environmental nditions would eventually demonstrate the most suitable conditions. Places could then be chosen to ve the best results.

In the choice of areas for experimental layings many factors are involved, the relative importance which is not yet fully understood. Some of the conditions thought to be favourable are:

(*a*) a considerable amount of shelter;
(*b*) a stable but not soft substratum;
(*c*) freedom from excessive silt suspended in the water;
(*d*) a relatively high water temperature in summer;
(*e*) a salinity which does not often fall significantly;
(*f*) freedom from gross pollution, either industrial or from sewage.

The hope that small-scale oyster farming, using relaid stock, might be a useful secondary occupation crofters and inshore fishermen also influenced the choice of experimental sites. A preliminary inspection charts showed areas likely to have the right conditions. If a visit to the selected areas confirmed their obable suitability, small experimental layings were made, using imported French oysters from Brittany, 2 and 3 years of age. These were used because they formed the only reliable and fairly uniform source young oysters free from pests and available throughout the course of the experiments. A few thousand sters were laid on selected ground at about the level of low water of spring tides and their subsequent ogress followed by measurements generally made once or twice each year. These measurements were:

(1) the antero-posterior diameter;
(2) the dorso-ventral diameter;
(3) the condition factor, or index of condition.

The means of the diameter measurements were used to give a growth curve for each laying (Fig. 9).

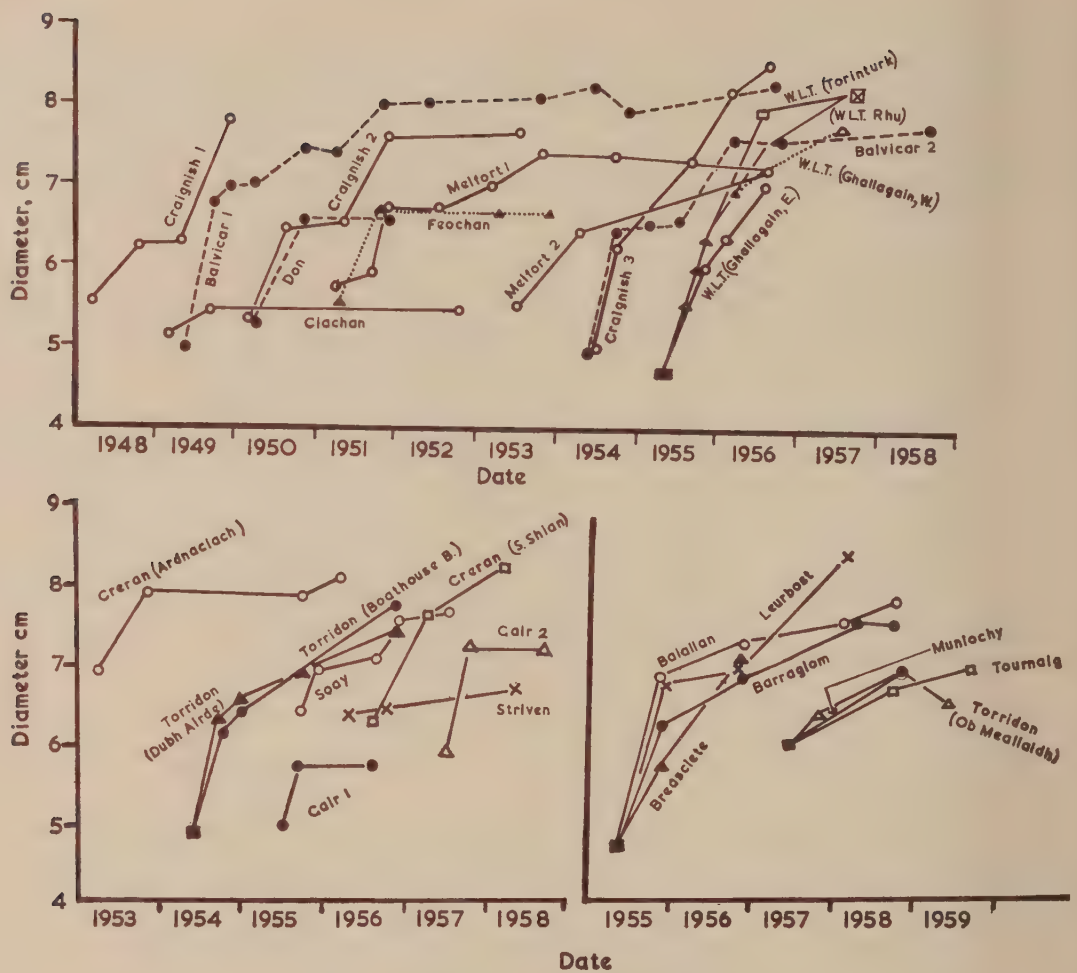


Fig. 9 Growth of relaid Brittany oysters.

The use of means is not ideal, as Hopkins, Mackin and Menzel (1954) have pointed out, but would appear to be the only practicable course in field experiments.

The condition factor, i.e. the ratio, volume of flesh to volume of cavity between shells, was measured during the season when oysters are marketed. This index of condition was developed and used in the U.S.A. by Wahl and Townsend (McKernan, Tartar and Tollefsen, 1949) and has been used in Britain for some years both by scientists of the Ministry of Agriculture, Fisheries and Food and by the author. A system of rating, drawn up by Dr. Cole, relates the condition factor to the grading which oysters would get in the market, as shown in Table VI.

TABLE VI

RELATION BETWEEN CONDITION FACTOR AND MARKET RATING OF OYSTERS

Condition factor	Market rating
0·34 and below	Very unsatisfactory
0·35–0·39	Unsatisfactory
0·40–0·44	Poor
0·45–0·49	Moderate
0·50–0·54	Satisfactory
0·55 and over	Very satisfactory

The condition factor, although a useful guide to the success of oysters laid in a given area, must be with some caution, as the following example shows. Native oysters from Skye were compared with same number of oysters, matched for size, from the Menai Strait, details of which were provided by Cole, and the results are shown in Table VII. The oysters from Skye, which were in excellent con-n, had a lower mean condition factor but a higher mean volume of flesh than those of the same size the Menai Strait. This anomaly is explained by the smaller shell volume of the Skye oysters, for an er of given total volume, which leaves a greater cavity between the shells. It may, therefore, be tioned whether the condition factor can be properly applied as a comparative test of oysters of rent origins, but it remains a satisfactory means of comparing samples of oysters of the same origin n used to test fattening in different areas. Baird (1958) also discussed the sources of error in using method.

Table VII

COMPARISON OF DIMENSIONS AND CONDITION OF OYSTERS FROM SKYE AND MENAI STRAIT

	Mean diameter (cm)	Mean total volume (ml)	Mean volume of shells (ml)	Mean volume of flesh (ml)	Mean condition factor
Skye	7·00	32·50	17·70	7·10	0·48
Menai Strait	7·02	32·09	20·11	6·69	0·56

The reliability of the standards used in assessing the fattening properties of different grounds was ied by comparing oysters from a number of experimental grounds with those from commercial in Essex supplied by Mr. G. D. Waugh of the Fisheries Laboratory, Burnham-on-Crouch. The ts of condition measurements are compared in Table VIII.

Table VIII

CONDITION FACTOR OF OYSTERS FROM ESSEX AND FROM SCOTTISH EXPERIMENTAL LAYINGS

Place		River Colne, Essex	Common Shore, R. Roach, Essex	West Mersea, Essex	West Loch Tarbert	Munlochy Bay	Ob Mheallaidh, L. Torridon	Barraglom, Lewis	Balallan, Lewis
e sampled		7.11.58	7.11.58	7.11.58	28.10.58	15.10.58	17.10.58	15.11.58	15.11.58
	0·39 and below	15	90	5	5	10	15	45	90
	0·40–0·44	50	5	20	15	25	30	35	10
tribution	0·45–0·49	25	0	35	25	40	20	20	0
condition	0·50–0·54	10 (35)	5 (5)	30 (75)	25 (80)	25 (65)	25 (55)	0 (20)	0 (0)
or	0·55 and over	0	0	10	30	0	10	0	0

According to Mr. Waugh the oysters from the River Colne were, at the time of taking the sample, it 10% below the condition in 1957 and 15% below that in 1956. The oysters from West Mersea the River Roach were also below the standard of the previous two seasons. It is evident from the lts that, on this occasion, the sample from the experimental ground giving the best rating (West n Tarbert) was rather better than the best of the Essex samples (West Mersea), and the worst of the rimental ratings was about the same as the worst of the Essex samples. These comparisons, supported personal judgment of the samples, give added confidence in the standards of condition used through-the experiments on growth and fattening.

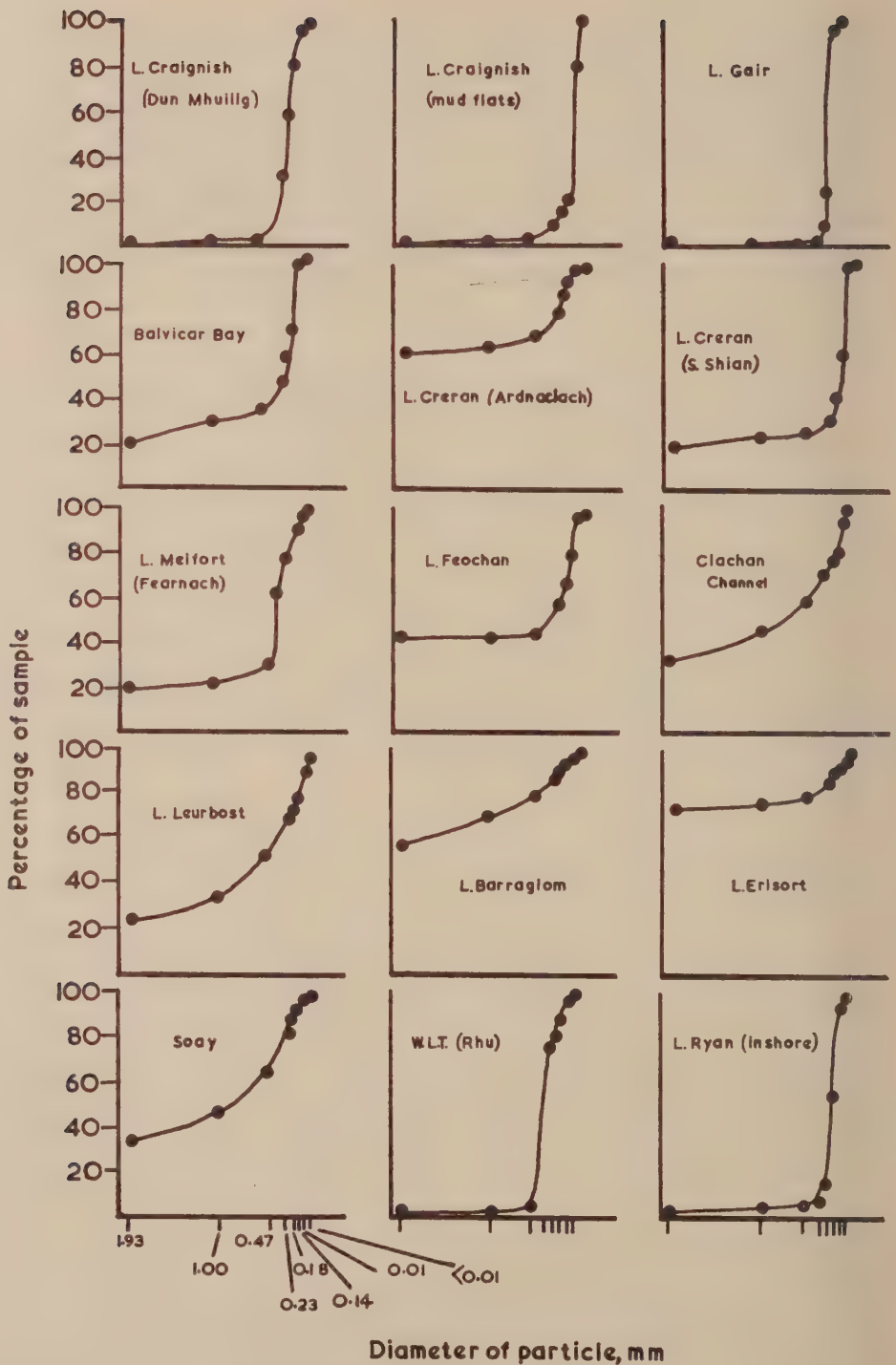


Fig. 10 Analyses of particle sizes of substratum on experimental layings, shown as cumulative percentages.

The mortality is important but difficult to measure in oysters laid on the shore, as the empty shells ıd to be scattered and carried away by waves and tide; no accurate estimate of mortality on the shore ·ings was, therefore, made.

In addition to the measurements of the oysters, some estimate was made of the local environmental ıditions. Unfortunately, owing to the number and remoteness of the layings it was not possible to take :ords of temperature and salinity sufficiently often to be of much value. One factor that could be :asured, however was the nature of the substratum. Samples were taken and analysed by the method Krumbein and Pettijohn (1938), as described by Holme (1954). The distribution of particle sizes, pressed as a curve of cumulative percentages, for each area, is shown in Fig. 10.

Experiments were started in 1948 and the number, date, and duration of the tests varied from place to ıce. In the following account areas are considered in geographical order. The author wishes to thank r. G. R. Brill, Mr. C. J. Harley and Mr. J. N. Thomson, who have helped in various ways with these periments.

ɔch Craignish, Argyll (Fig. 11)

This loch, which is about 5 miles long and open to the south-west, is largely exposed to the prevailing nds. Good shelter is obtained behind the line of islands along the north shore and in bays such as Dun huilig Bay. The main part of the loch is deep, but at the head, between Eilean Mhic Chroin and the rth shore, and also in Dun Mhuilig Bay there are large areas of shallow water and foreshore. According a memorandum by W. L. Calderwood to the Fishery Board for Scotland, the head of the loch offered ɔottom of "high quality" where a few living oysters were found.

Danger from pollution hardly exists, there being only a few houses round the shores and one small lage. The large body of water in the loch and its open character remove all danger of low salinities, cept near the mouths of the few streams. Salinities at low water on 27th September, 1958 were 34·0‰ Dun Mhuilig and 28·0‰ over the flats. Most of the large tidal mud flats stretching between Eilean hic Chroin and the north shore were found to be unsuitable for laying oysters as the mud is too soft d the flats are exposed for too long a period during the ebb.

The substratum of Dun Mhuilig Bay is a mixture of sand and mud in proportions which can be garded as nearly ideal (Fig. 10), in view of the very good results obtained in repeated tests (Fig. 9). ıe area of first quality ground amounts to about 3,000 sq.yd (2,520 sq.m), sufficient for about 90,000 sters. The water of Dun Mhuilig Bay is fairly free of silt, but over the mud flats it holds a considerable antity of fine particles in suspension, probably owing to the nature of the substratum. Oysters from ittany were laid in Dun Mhuilig Bay in 1948, 1950, 1954 and 1955 and on the soft mud flats in 1954.

Growth of oysters in Dun Mhuilig Bay was good, not only in the first year but also in subsequent ars. Growth on the soft mud flats was somewhat slower. Oysters in Dun Mhuilig Bay fatten consistently ch year and are generally in best condition in the autumn and early winter (Appendix). The fattening ɔperties of the soft mud flats, so far as they can be judged from the samples taken, are not very different. ın Mhuilig Bay is now regarded as one of the best of the experimental oyster grounds for growth and tening and can serve as a standard when comparing other areas.

est Loch Tarbert, Argyll (Fig. 29)

In this area, both littoral and sub-littoral layings of oysters were made. The latter are dealt with in tail in the section of this report on the 3 years' experiment in West Loch Tarbert (pp. 53-68) and only tails of the shore laying are given here.

West Loch Tarbert is an inlet on the north-western part of the Kintyre peninsula. It is about nine les long, averages about half a mile in width and is protected from heavy seas by a constricted shallow ɔuth and by an island. There are considerable stretches of shore on the south of the loch, extending ɔm the southern half of Gartnagrenach Bay to a point about a quarter of a mile farther south. This has en called the Leamnamuic ground, after the farm of that name. Shelter is adequate, although the

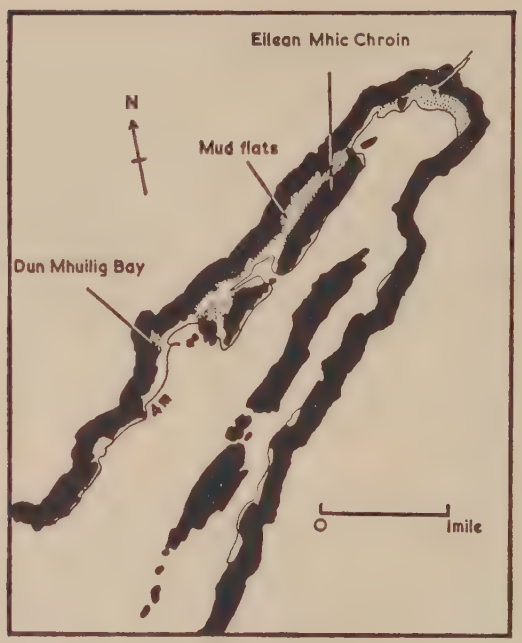


Fig. 11 Sketch map of Loch Craignish, to show degree of shelter, extent of foreshore (stippled) and water of less than 4 m depth.

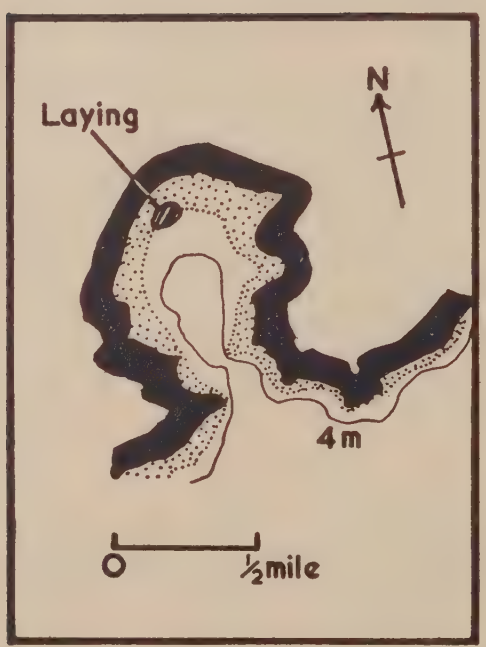


Fig. 12 Sketch map of Loch Gair, to show degree of shelter, extent of foreshore (stippled) and water of less than 4 m. depth.

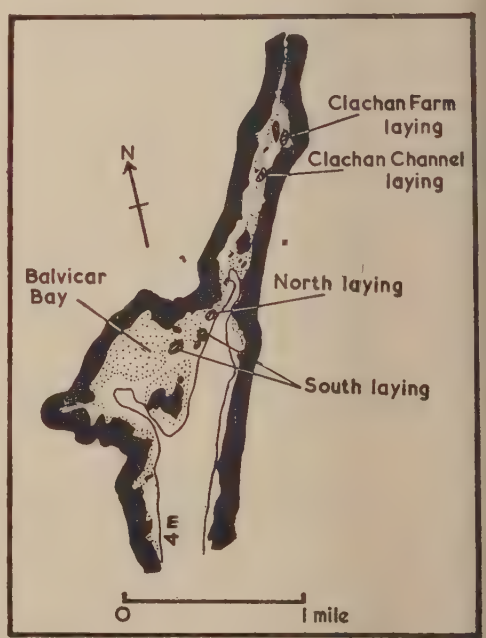


Fig. 13 Sketch map of Balvicar Bay and Clacha Channel, to show degree of shelte extent of foreshore (stippled) and wate of less than 4 m depth.

ıd is somewhat exposed to the north and west. A large area of shallow water and intertidal sand s to the south-west should lead to appreciable local heating. There is no danger of pollution or ɔed salinity. The substratum is firm, consisting mainly of coarse sand and grit, with broken shell, there should be little suspended matter in the water. The area is about 50,000 sq.yd (42,000 sq.m), ıough for over a million oysters. A laying was made in August 1956, consisting of 1,000 oysters ged from an earlier sub-littoral laying at Ploc Airde, nearer the head of the loch.

Growth between August 1956 and October 1958 was slow, and it appears that this area is not one vhich a quick return is to be expected. The single measurement of condition gave poor results ɔendix). These results for growth and fattening suggest that the foreshore of West Loch Tarbert is ı less satisfactory than the sub-littoral areas. A possible reason for this, the long period of exposure w water, is mentioned elsewhere (p. 57).

ı Gair, Argyll (Fig. 12)

Loch Gair is a small, almost circular inlet, slightly over half a mile in diameter, leading off Loch :. The narrow mouth provides very good protection from nearly all directions. Only a small part of och exceeds 6 m in depth, and much of it is 4 m or less. Large areas of foreshore are exposed at low r, and considerable local heating should result. Salinity is unlikely to be seriously reduced, except the mouths of the streams crossing the shore. At the laying nearest to a stream surface and bottom ities of 17·7‰ and 27·5‰ respectively were recorded at low water on 26th September, 1958. There danger of sewage pollution from the village of Loch Gair, but the tidal exchange of water in this ow inlet would limit the danger, except near sewers.

The substratum (Fig. 10) is a sandy mud over a large part of the north and west shores firm enough ɔld oysters and to walk on, but the percentage of fine particles is sufficient to encourage the worm *lora ciliata,* and to cause some suspended silt. An area of some 4,000 sq.yd (3,360 sq.m) of uniform ɔ exists near low water line on the north and west shores and this should take at least 100,000 oysters. shore the bottom quickly becomes very soft and unsuitable for laying oysters.

Brittany oysters of the 1955 importation were dredged from West Loch Tarbert and laid on the eyed shore in Loch Gair in June, 1955. A second laying of Brittany oysters, imported when 3 years was made in June, 1957 on firmer ground, some 20 yards inshore from the first laying, which was ght to be on slightly too soft ground. Oysters of the first laying maintained a satisfactory growth which was, however, rather less than that of similar oysters on sub-littoral layings in West Loch ɔert (Fig. 9). Results from the second laying show a higher growth rate, and the area can be con-ɔd satisfactory for growth. The condition of samples (Appendix) indicates that fattening will also, eneral, be satisfactory. The site is, therefore, regarded as a good one for relaying. However, the alence of *Polydora ciliata* in the shells of the oysters is a disadvantage, as the burrows of the worm ɛr the shell brittle and unsightly, and, if numerous, may reduce the market value of the oysters. ɔrding to Young (1888) a local proprietor started oyster cultivation in Loch Gair in the second half st century with some success until the oysters were stolen by fishing boats.

vicar Bay, Argyll (Fig. 13)

Balvicar Bay is about ¾ mile long by ½ mile wide and very shallow, with about 100-150 acres of fore-e exposed at low tide. The bay is well protected from all directions and wave action is never severe. large area of foreshore allows considerable local heating. There is little reduction of salinity, as shown eadings of 30·6‰ and 32·6‰ at low water on 28th September, 1958. Balvicar village is not a serious ce of pollution as rapid tidal currents ensure adequate water exchange over the oyster grounds.

The substratum varies from a firm mixture of sand and slate debris at the north end of the bay to ry soft black mud in the more sheltered parts. Large areas of the shore are of good consistency and r softer parts could be rendered more suitable by the addition of sand, pebbles or shell. Soil analyses ɛ two experimental areas show a higher proportion of medium and large particles than Loch Craig-

nish (Fig. 10). Waves induce a considerable amount of suspended silt in the southern, protected part the bay, but the northern section is free from this effect. The area available is at least 10,000 sq (8,400 sq.m) in the northern part of the bay, and could take a stock of ¼ to ½ million oysters.

Two layings of Brittany oysters were made, the north laying in 1949 and the south laying in 19 the latter being a few hundred yards from the former and on softer ground. In both layings a mode and fairly satisfactory growth rate was maintained over several years (Fig. 9). The series of observati on the condition of the 1949 laying (Appendix) showed, in general, a high and rising value during cessive winters. The values in spring tended to be lower than those in autumn and early winter, a fea also noted in Loch Craignish. The figures for the layings made in 1954 are generally considerably lo The softer substratum of the adjacent areas of the inner bay results in more silt becoming suspende the water, which may interfere with feeding and thus reduce the condition. Balvicar Bay is a us area for growing and fattening oysters.

Loch Creran, Argyll

This loch is 6 miles long and opens to the west by a narrow entrance. It is divided into an in constricted basin, 2 miles long, and an outer basin about 4 miles long by one mile wide, generally depths of less than 20 m. During the latter part of the 19th century Mr. W. A. Smith and Mrs. Ogi of Barcaldine carried out experiments, mainly concerned with the collection of spat (Young, 18 but the experiments appear to have failed. Layings in the present series were confined to two place the shore of the outer basin, Ardnaclach and South Shian Bay.

Ardnaclach

This, one of several similar places on the north shore, is in a bay protected from the prevai south-west winds but somewhat exposed to the south. There is no extensive area of adjacent shal water and little local heating is to be expected. No streams of importance enter the loch near the exp mental laying and the water attains almost full salinity. There is no possibility of pollution from sew The soil is a coarse, gritty sand (Fig. 10) and consequently the water is clear. This shore has at l 5,000 sq.yd (4,200 sq.m) of such ground and it is possible that sub-littoral areas might also be found similar nature. The littoral ground alone would take at least 150,000 oysters.

A laying was made in 1953, the two years old stock having been imported from Brittany in 1 and kept in the Menai Straits by the Ministry of Agriculture, Fisheries and Food until March, 1 Growth in the first year after laying was satisfactory and thereafter rather slow (Fig. 9). The condi factor of all samples was good (Appendix). This shore can be classed as moderately good for growth satisfactory for fattening.

South Shian Bay

This bay, which lies on the south shore of Loch Creran some distance from the entrance, is expo to the east only and seldom suffers from wave action. Some neighbouring shallow water and the consi able extent of foreshore should ensure useful local heating. The salinity is unaffected by streams, as sh by a value of 31·7‰ at low water on 29th September, 1958, and there is no danger of pollution f sewage. The soil is a fairly uniform muddy sand (Fig. 10), quite firm and stable, and very little suspen matter is present in the water. There is an area of 4,000-6,000 sq.yd (3,344-5,017 sq.m) of similar sh in the part of the bay which was surveyed and probably more in adjacent bays. The ground would a stock of from 100,000 to 200,000 oysters.

A laying of 2,000 three-years-old Brittany oysters was made in 1956. The oysters grew well in b the first and second years of the experiment (Fig. 9), and this part of Loch Creran seems to give be growth than Ardnaclach, perhaps owing to higher temperatures resulting from local heating in sha water. The three measurements of condition factor indicate moderately good fattening (Appendix), more results are needed, especially covering the early part of the winter. This shore is regarded promising site.

Melfort, Argyll

Loch Melfort is an inlet 3 miles long and $\frac{1}{4}$ to $\frac{1}{2}$ mile wide, and opening to the south-west. Although ntrance is protected by islands the sea may be sufficiently rough to disturb oysters laid on the shore. bays at the head of the loch, Loch na Cille and Fearnach Bay, are more sheltered and experimental igs were made in both places.

ch na Cille

This is a narrow bay with its long axis running east and west. It has a fair degree of shelter, except ıg westerly winds, when oysters on the shore are sometimes moved. The small extent of shallow water he adjacent deep water which quickly runs off to 40 m, keep the water temperature low. There is little ction of salinity near the layings, and no danger of pollution. The substratum consists of a mixture bbles and coarse sand and no excessive silt should be present in the water. The experimental oysters rather slowly and did not reach a large size even after 5 years. Fattening was only moderate.

arnach Bay

The north-western part of this bay is adequately protected from most directions but the deep off- water, which tends to remain cold, is a disadvantage. A river enters at the head of the loch but, g to the distance, will not affect the salinity at the laying. There is no pollution. The substratum ebbles, shingle, and coarse sand (Fig. 10) is stable and should ensure clear water. There is enough nd for 50,000 oysters. The growth on this bed was slightly better than in Loch na Cille, but was h slower than on good oyster grounds. Oysters would probably fatten quite well on this laying in l years, as is indicated by the condition factor measured in 1956 (Appendix), but sufficient results not available to allow an accurate estimate. Oysters could be grown and fattened in parts of Loch fort but it would take several years before they were ready for sale, and this area is not classed amongst best oyster grounds tested. Mr. J. A. Billmeir kindly granted access to the layings of oysters which he e in Loch Melfort.

h Feochan, Argyll

Details are not given as this area is considered to be of little value. Oysters were laid in 1951 but growing quite well in the first season failed to grow appreciably in the following two years. The k was then transferred to other grounds. The condition of the oysters in the three samples examined poor (Appendix).

h Don, Isle of Mull, Argyll

A laying of two-year-old oysters was made on the north shore of Loch Don in 1950. In their first on the oysters grew satisfactorily but showed no measurable growth in the following year. This is lar to the behaviour of oysters laid elsewhere on ground that proved to be unsuitable. Two samples, ı taken in October, when oysters are usually in good condition, gave low condition factors (Appendix). curious that the experiments in Loch Don were such a decisive failure, since Calderwood, in a report he files of the Scottish Home Department, recommended it strongly and started some experimental ngs, the results of which have not been traced. Calderwood's main objection to Loch Don was the large proportion of the water which left the area during each tidal cycle, carrying with it most of larvae that might be produced. This objection is valid but it now appears that Loch Don is also atisfactory as a growing and fattening ground. Calderwood suggested that a dam might be built oss the mouth of the loch to impound the waters and convert the area into a breeding place, but the eme was abandoned.

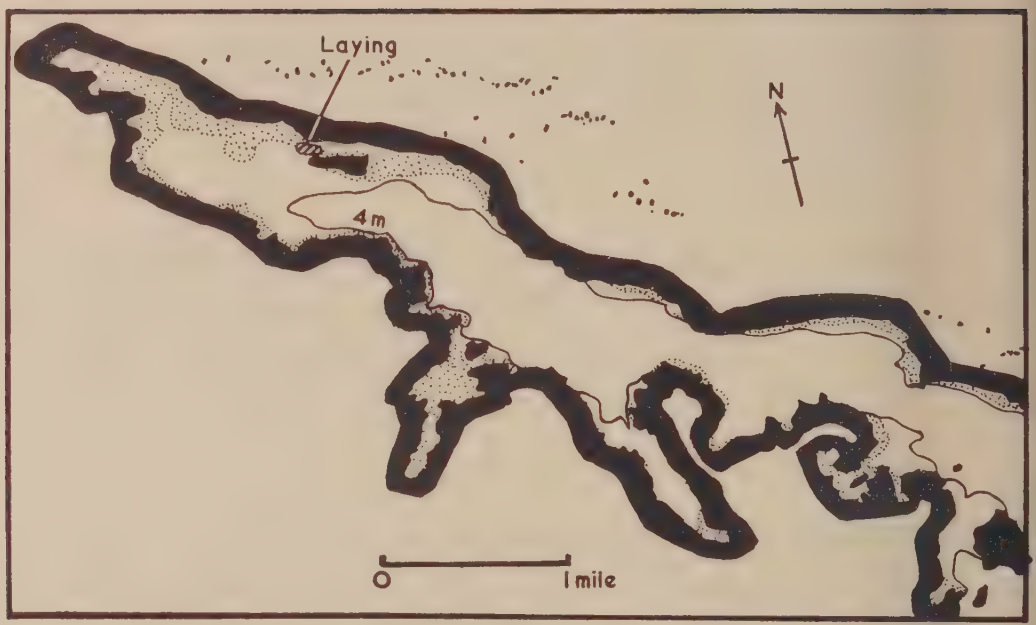


Fig. 14 Sketch map of Loch Leurbost, to show degree of shelter, extent of foreshore (stippled) and wate less than 4 m depth.

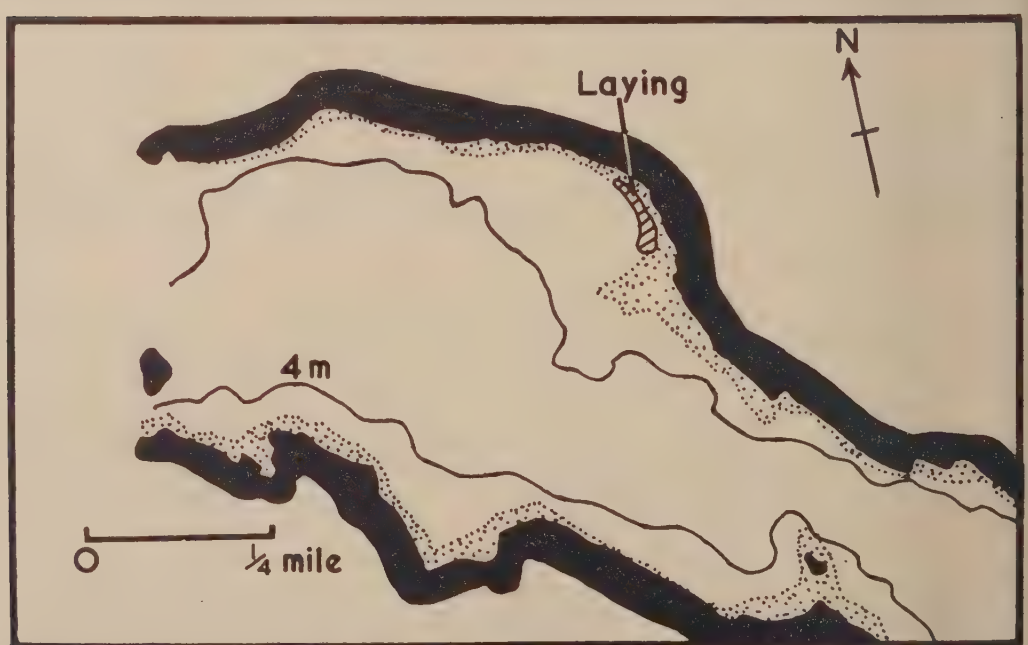


Fig. 15 Sketch map of Loch Barraglom, to show degree of shelter, extent of foreshore (stippled) and wat less than 4 m depth.

ch Striven, Argyll

A laying of three-years-old oysters was made at the head of Loch Striven in 1956. Growth, although ntained after the first year, was slow (Fig. 9). A sample in the first year of the experiment showed te good fattening, but 18 months later the oysters were thin (Appendix), and, moreover, had a bitter allic flavour. This site is unfavourable for oysters.

achan, Seil, Argyll (Fig. 13)

Two experimental layings were made in 1949, one known as Clachan Channel and the other as chan Farm. Measurements of the oysters at Clachan Farm revealed slow growth in the first year and appreciable growth thereafter. The condition factor of samples from both layings was low (Appendix). at the poor results were not due to any peculiarity of the consignment of oysters or of the season is nonstrated by the satisfactory growth and fattening of oysters from the same importation laid in vicar Bay at the same time. The area at Clachan has no value as an oyster ground.

e of Lewis

The coast of Lewis is much indented by narrow, sheltered inlets, some of which are long and sinuous. ese inlets have features favourable to oyster culture, especially for the retention of larvae during the eding season. Suitable foreshore or sub-littoral ground, however, is limited by the rocky and steep ure of the shore in some places and by a thick deposit of soft mud in others. A few of the places surveyed re chosen for experimental layings.

h Leurbost (Fig. 14)

This loch is narrow, about 2½ miles long, and well protected by islands at the entrance. The north re of the seaward half of the loch has few beaches suitable for oysters, but for about half a mile from head of the loch the shore shelves gently. Here there is some danger of pollution from the nearby vnship of Leurbost, but reduced salinity is unlikely as there are no large rivers. The shore consists of a xture of pebbles and firm mud, or in places grit with some dead shell (Fig. 10), and is large enough hold 200,000 oysters. Little silt is expected in the water. Dead oyster shells and a few large and small ng oysters indicate conditions suitable for the species. Near the mouth of the stream entering the ad of the loch there are many exceptionally large specimens of *Anomia ephippium* L., perhaps indicating od conditions for lamellibranch feeding.

A laying of 1,000 two-years-old Brittany oysters was made near the village of Leurbost in May, 55. The growth rate (Fig. 9) has been fairly satisfactory during the three years of the experiment. ttening was also satisfactory. The upper reaches of Loch Leurbost appear to be favourable for growing d fattening oysters.

Loch Barraglom (Fig. 15)

This narrow stretch of water separates Lewis from the island of Great Bernera. The only part amined in detail was the shore at Tob Millegradha on the southern shore of Great Bernera. The area well protected from all directions and the beach slopes gently. The off-shore water is between 4 and 6 m depth, and there should be some degree of local heating. There is no danger from reduced salinity or llution. The substratum is mainly pebbles overlying gritty sand, with coarse muddy sand in places d a few stony areas (Fig. 10). This substratum, with the degree of shelter available, should ensure clear ter. The suitable ground amounts to about 1,500 sq.yd (1,260 sq.m), and would take 50,000 oysters. owth of the oysters laid in May, 1955 was moderately good (Fig. 9). Fattening was also fairly satis- tory (Appendix). This site is of moderate value.

Loch Erisort

Part of the shore near Balallan village was the site of a laying of 1,000 Brittany oysters in May, 1955.

Growth was good in the first year and slow thereafter (Fig. 9); fattening was poor (Appendix). Possib the amount of silt in the water interferes with feeding. Loch Erisort does not seem to be a good site f relaid oysters.

Breasclete Bay

A laying was made in May, 1955. This experiment ended in less than two years and the resul obtained (Fig. 9) indicate only moderate growth. Fattening seems to be very poor (Appendix). Breascle is classed with Loch Erisort as a rather unfavourable area.

Little Loch Roag (Fig. 16)

This loch, about 4 miles long by ¼ mile wide, is joined by a narrow channel to the more open b still sheltered waters of West Loch Roag. It is, therefore, well protected. The seaward half reaches 14 in depth; the landward half varies mainly from 3 to 6 m and for about a mile at the head of the lo the depth is less than 2 m. That these conditions favour breeding is demonstrated by the continue survival of a self-maintaining stock of oysters. In two parts of the loch which were examined in deta oysters were plentiful on the lower part of the shore and in shallow water. Most of them were attache to small stones, dead mussel shells or the shells of living mussels. Oysters and mussels were the mo conspicuous of the larger animals, few other species being seen. On a number of other shores, which we not visited, oysters were also said to exist.

Fig. 16 Sketch map of Little Loch Roag, to show degree of shelter, extent of foreshore (stippled) and water of less than 4 m depth.

Little Loch Roag is in many respects like Linne Mhuirich, Loch Sween. Each is a long narro shallow inlet with a constricted mouth and each has the conditions necessary for the high summ temperatures and good retention of larvae which favour successful breeding. Little Loch Roag has th additional advantage of possessing a large area of shallow water where the bottom consists of a mixtu of gritty sand, pebbles and mud, very suitable for taking relaid oysters. It is likely that the natural spatfal could be increased by laying culch. The introduction of more oysters to augment the breeding sto might also help, but these would have to be of a stock adapted to breeding at the prevailing temperatur

Isle of Soay

The co-operation of Major A. H. Arthur in experiments with oysters laid on Soay in 1955 is ac nowledged. The area is in Soay Harbour, a narrow, sheltered inlet facing north-west, which becomes lagoon with about 15 acres of water at low tide. A little fresh water enters the bay. The soil analys (Fig. 10) indicates a substratum with a fairly high proportion of coarse particles, and there should b little suspended silt. The rate of growth is moderate. The condition of the oysters sampled was po (Appendix) and this ground must be considered unsatisfactory.

i Torridon, Wester Ross

This is a large body of water, divided by a narrow neck into an outer and an inner basin. Only nner basin (Upper Loch Torridon) was surveyed. This is nearly 5½ miles long by about 1½ miles wide much of it is over 60 m in depth. The three experimental sites chosen are described below.

Mheallaidh

This bay is sheltered and opens to Upper Loch Torridon by a narrow, shallow mouth facing north. rt half of the total area of the bay dries at low water and much of the remainder is only 1 to 3 m deep. l streams enter at the south-west and south-east corners of the bay, but neither is likely to reduce alinity except very locally. There is no danger of pollution. The south-east and south-west shores of Mheallaidh consist of a mixture of gritty sand, pebbles and shell and the overlying water is believed clear. The total area of good substratum is about 4,000 sq.yd (3,360 sq.m), enough to hold 100,000 ts.

A laying of three-years-old Brittany oysters was made in June, 1957. The growth rate appears to be erate (Fig. 9) and in average or warm seasons is expected to be fairly satisfactory, but not high. A measurement of condition was made and shows a moderately satisfactory result (Appendix). This riment is being continued, the results obtained so far being encouraging but not such as to suggest ound of high quality.

ubh Airde Bay

This bay is exposed only to the north. A small amount of foreshore is available and the off-shore r is 10 m deep at the mouth of the bay; little local heating can therefore be expected. There is no ced salinity and no danger of pollution. At the level of low water and a little below it, the bottom m and consists of finely broken shell which should ensure water relatively free of silt. Between 1,000 2,000 sq.yd (840 and 1,680 sq.m) of suitable bottom could take at least 50,000 oysters.

Three-years-old Brittany oysters were laid here in the spring of 1954. These have grown satisfactorily ighout the years of the experiment, but as one exceptionally warm summer (1955) is included in period, the typical growth rate may be rather less. The single measurement of condition gave a erate result (Appendix) but data are insufficient.

oathouse Bay

This small bay, a short distance west of Ben Damph House, is sheltered from all directions except the 1. An extensive tidal flat adjoining the site together with the adjacent shallow water should ensure heating. A large stream enters one end of the bay so that at times of heavy rain the salinity in the n may be much reduced; there is no danger of pollution. The stable bottom consists of a mixture bbles and mud, which should ensure fairly clear water. The available area would hold from 10,000 0,000 oysters.

An experimental laying of three-years-old Brittany oysters was made in 1954. Growth has been at as good as in Dubh Airde Bay. No measurements of condition were made, but the few oysters nined on the site were not fat and this area must still be regarded as of doubtful value for relaying rs. The results from the last two areas of Loch Torridon have been obtained through the courtesy e late Lady Diana de Hosszu, who started experimental layings. After her death the work was rvised by the Earl of Lovelace who granted access to the area.

h Ewe, Wester Ross

Loch Ewe is a large body of water much of which is more than 30 m deep. The shallow southern arm includes an area of about 3 square miles which is mostly less than 9 m in depth. Oysters formerly obtained from the head of this arm of the loch in great quantity and according to the Mrs. Sawyer of Inverewe House they used to be removed from the shore in cart loads and sent to rness. Experiments were carried out by the late Captain Sawyer to establish a system of oyster

culture in Loch Ewe. Details are not available but Captain Sawyer concluded that mortality on the be was normal, that rate of growth and fattening were good and that the finished product would rank 'native'. Apparently, however, few spat settled on any of the collectors which were laid out.

Loch Tournaig

In Loch Tournaig, a branch of Loch Ewe, the site surveyed was Bagh Ard na Ba, a small shelter bay, mostly less than 4 m in depth, where there is no risk of reduced salinity or pollution. Native oyste which were known to Calderwood, still exist here although in small numbers. The late Captain Sawy has stated that some time between 1920 and 1930 as many as one hundred dozen oysters were collect from Loch Tournaig during one tide. Seven hundred three-years-old Brittany oysters were laid at Ba Ard na Ba in the spring of 1957. Results are still insufficient for reliable assessment, but the growth ra seems to be only moderate (Fig. 9). As the summers of 1957 and 1958 were cool, however, normal grow at this site may be better than the results indicate. The single measurement of the condition factor w moderately satisfactory (Appendix). Results justify the continuation of the experiment.

Inverness Firth

The south shore of Inverness Firth was surveyed as far east as Alturlie Point. Most of this ar was found to be unsuitable since the substratum consists of pure sand with scattered, embedded ston and a good deal of *Laminaria*. On the north-west shore of the Firth only Munlochy Bay was visited low water.

Munlochy Bay

This bay, extending in a westerly direction from a point half-way along the north-west coast Inverness Firth, is adequately sheltered from all directions except the east. At low-water of spring tid only a narrow, shallow channel remains flooded. Local heating may raise the temperature within t bay considerably. Moreover, water entering the bay from Inverness Firth, much of which is less than 5 deep, should be warmer than the open sea during the summer. The stream entering at the head Munlochy Bay does not collect water from a large catchment area; this fact, together with the lar exchange of water between the bay and Inverness Firth should ensure that salinities are not low. T nearest major source of sewage and industrial pollution, at Inverness, is 4 miles distant and is unlikely constitute a danger; but tests for bacterial purity would have to be made before oysters could be exploite The substratum of the upper shore is soft mud and the lower part consists in some places of sand thro into ridges and hollows and in others of smooth sandy mud with very few casts of *Arenicola* and no rip marks which would indicate unstable soil. These latter areas seem to be suitable for oyster layings b the extensive areas of soft mud may produce silt-laden water under wave action.

An experimental laying of three-years-old Brittany oysters was made in Munlochy Bay in Jul 1957. During 1957 and 1958 the oysters grew at a moderate rate (Fig. 9), but more results are need The result of the single measurement of condition was satisfactory (Appendix). This experiment is to continued.

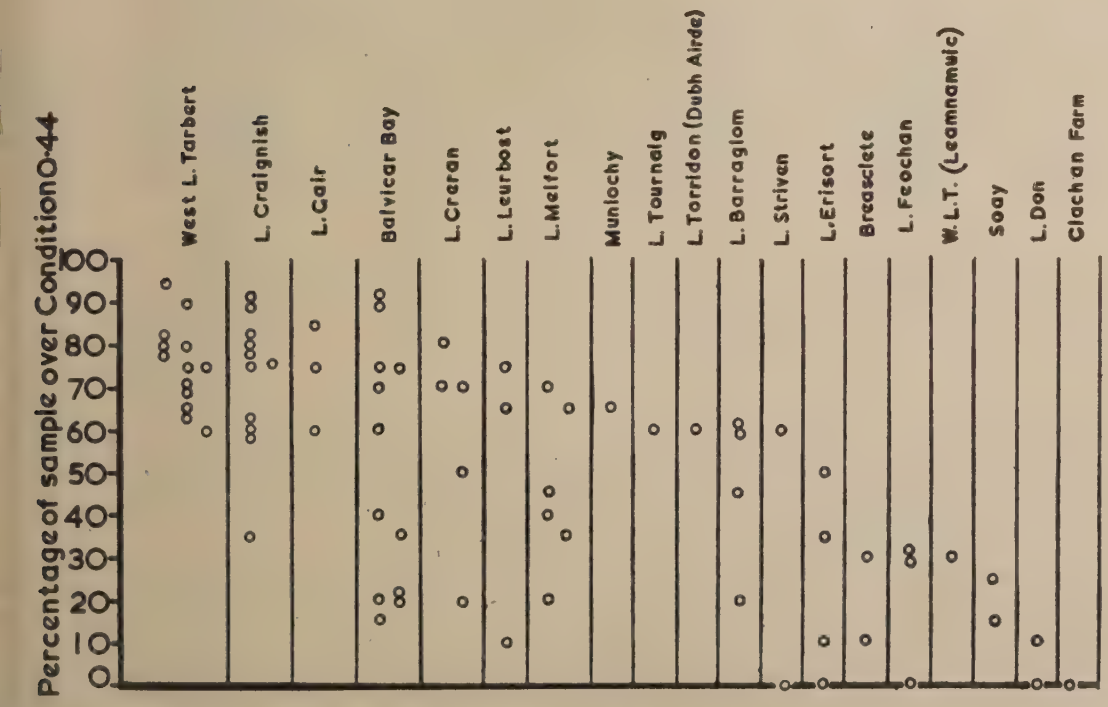
Discussion of Experiments on Growth and Fattening

The aims of these experiments have been to find places where oysters can be grown, and to le more about the factors which determine whether a given area will be suitable or not for growth a fattening. The answer to the first question has been given in detail in the foregoing account of the exp mental layings.

The second question is more difficult and concerns the ecology of the oyster. Foremost amon the difficulties is incomplete knowledge of the effect of various environmental factors on the grov and fattening of oysters. Much of the work in this field has been done on the American species *Crassos virginica* Gmelin, especially by Loosanoff and his co-workers, whose results may not apply to *Ostrea edu*

Growth and fattening may demand slightly different environmental conditions but a ground to be eful must promote both, except when stock can be transferred from a growing to a fattening area, and is practice is usually possible only in the larger fisheries. In arranging the experimental layings in der of merit, the criterion has, therefore, been the best combination of growth and fattening. The best ounds gave both good growth and good fattening and on the worst grounds both growth and fattening ere poor, but some features of the experiments have made it difficult to assess with accuracy the relative erits of the grounds. As the experiments had to be carried out over a period of years, different consign- ents of French oysters were used on the various grounds, and these consignments may have varied in eir inherent growth characteristics. Another variable factor has been the weather with the influence exerts on temperature, salinity and degree of wave action of inshore waters. Some layings were made in ars with hot, dry summers, such as 1949 and 1955, and others in cold, wet years, and these differences ust to some extent vitiate comparisons of the resulting growth and fattening. The variation in the nount of food available in the different years is also an unknown factor. For these reasons areas should tested by layings made in more than one year, but in practice this has been possible in a few cases ily. In spite of these difficulties, it has been easy to separate the very good from the very poor areas so at the real problem has been the exact ranking of the grounds and the estimation of the value to be aced on the moderately good grounds.

Fig. 17 shows the areas arranged in order of merit, and also the percentage of oysters in each sample ving a condition factor greater than 0·44, this percentage being taken as an index of the merit of the ounds. The ranking is, of course, approximate and some experiments are still too recent to have yielded ore than one result.



ig. 17 Condition factor of oysters on experimental layings. Each circle represents, for one sampling date, the percentage of the sample with condition over 0.44.

Table IX shows the assessment of the areas and also gives an estimate of three factors thought t affect oysters, namely the amount of suspended silt in the water, the extent to which the salinity may b reduced, and the degree of local heating.

It is evident that no single factor accounts for all the good, or all the poor, results. The best com bination of conditions seems to be (1) a considerable amount of local heating, arising from the presenc of shallow water or intertidal sand and mud banks, (2) no serious reduction of salinity, and (3) wate containing a minimum of suspended silt. In the absence of local heating growth may continue, but wil be slowed down as occurred in Loch Striven and Loch Melfort. An area likely to yield marketabl oysters within two or three years of laying will require a considerable expanse of foreshore or adjacen shallow water.

TABLE IX

ASSESSMENT OF AREAS TESTED FOR GROWTH AND FATTENING, AND ESTIMATES OF SUSPENDED SILT, REDUCTION IN SALINITY, AND DEGREE OF LOCAL HEATING

Area tested	Amount of silt in water	Reduction in salinity	Degree of local heating	Rating of area
West Loch Tarbert				
Rhu	Little	Little	High	Very good
Island, E.	Little	Little	High	Very good
Island, W.	Some	Little	High	Very good
L. Craignish				
Dun Mhuilig	Very little	None	High	Very good
Flats	Some	Little	High	Very good
L. Gair	Some	Some	High	Very good
Balvicar Bay				
North	Little	None	Moderate	Good
South	Some	None	High	Moderate—good
L. Creran				
Ardnaclach	Very little	None	Low	Moderate—good
S. Shian Bay	Very little	None	High	Good
L. Leurbost	Little	Little	High	Moderate—good
L. Melfort				
L. na Cille	Very little	None	None	Moderate
Fearnach Bay	Very little	None	Low	Moderate
L. Barraglom	Very little	None	Low	Moderate
L. Striven	Very little	Possibly some	Low	Poor
L. Erisort				
(Balallan)	Much	Little	High	Poor
Breasclete	Very little	None	Moderate	Poor
L. Feochan	Little	Some or considerable	High	Poor
West Loch Tarbert (Leamnamuic)	Little	None	Moderate—high	Poor
Soay	Little	?	Some?	Poor
L. Don	?	Great	High	Very poor
Clachan	Much	None	Low	Very poor

The importance of temperature to the growth of *Ostrea edulis* was recognised by Korringa (1951 who found that, in Holland, although shell material was deposited as long as the water temperature wa above 10°C., an increase in diameter was only recorded at temperatures over 15°C. Walne (1958) foun an increase in diameter of oysters in Wales at temperatures above 12°C.

The importance of salinity is rather difficult to judge. The generally accepted opinion is expresse by Korringa (1957) who states that the flat oyster suffers at salinities of less than 23·0‰. Certainly, on number of grounds that were found to be poor in the present series of tests an important reduction i salinity occurs at least periodically as in Loch Don and Loch Feochan, which in all other respects appe to be suitable. However, it is possible for oysters to settle and to grow to adult size in waters where the is not only a slight, but periodically a very marked fall in the salt content. For instance oysters hav settled and grown on a tidal bank at the mouth of the River Ewe in Loch Ewe where the salinity mu have dropped at each spring tide to nearly that of fresh water.

The amount of silt in the water obviously varies a great deal, and depends not only on the nature the substratum but on the amount of wave action. How difficult this factor is to estimate is shown by e case of Balallan in Loch Erisort. The substratum in this locality contains only a very small proportion fine particles (Fig. 10) but the water readily becomes highly charged with silt and clay from the ighbouring shore and sub-littoral ground. That fine silt in suspension in the feeding water of the merican oyster *Crassostrea virginica* quickly reduces the rate of feeding was shown by Loosanoff and ommers (1948). The European oyster appears to be less well adapted to water of this kind, and it may supposed that both the duration and efficiency of feeding are seriously reduced by conditions such as ose found at Balallan. The failure of the layings at Clachan is also attributed partly to the concentration fine particles in the water.

These considerations may help in the choice of areas to be used for relaying oysters, but as Cole 956) says, the only way of determining whether a place is satisfactory is by a trial laying.

OTHER AREAS SURVEYED

In addition to the sites where surveys were followed by experimental layings which yielded results, veral places which were examined but not adequately tested remain to be mentioned. The merits of ese places can only be estimated from their physical characters.

INNE MHUIRICH, LOCH SWEEN, ARGYLL (Fig. 18)

The experiments in breeding oysters in Linne Mhuirich are dealt with elsewhere in the report p. 43-48). The area is well sheltered, with a mean depth of only a few metres, but no large foreshores e uncovered at low water. The shallow, sheltered water and small exchange with the open sea ensure nsiderable heating during the summer (see p. 44). As Linne Mhuirich receives fresh water from only few streams the danger of reduced salinity is very slight; there is also no risk of pollution. The area ailable for laying may be large enough for several hundred thousand oysters, but there are dangers the use of foreshores, which may be exposed for long periods during prolonged north-easterly winds.

TABLE X

CONDITION FACTOR OF NATIVE OYSTERS FROM LINNE MHUIRICH, 23.11.57

	Percentage of sample	
0·34 and below	10	
0·35–0·39	15	
0·40–0·44	40	
0·45–0·49	20	35
0·50–0·54	10	
0·55 and over	5	

No layings were made to test the suitability of the area for growth and fattening, but some observations large oysters used as breeding stock indicate that growth is rapid. A sample of native oysters taken m Linne Mhuirich on 23rd November, 1957, gave the condition factor results shown in Table X. lthough this area appears to be satisfactory for breeding and growth, the fattening characteristics quire further investigation.

Fig. 18 Sketch map of Linne Mhuirich, Loch Sween, to show degree of shelter, extent of foreshore (stippled) and water of less than 4 m depth. Suitable ground is shown hatched.

CH CRINAN, ARGYLL

This almost square inlet, about 1½ miles across, is exposed to the west and only the inner part is sheltered. The large flats uncovered at low water, although giving good prospects of local heating, too sandy except near the mouth of the River Add, where, however, the salinity is sometimes as low ‰ at low water. The area is, therefore, unsuitable.

ISTAFFNAGE BAY, ARGYLL

This large, well-sheltered bay has an expanse of foreshore apparently very suitable for oysters. c, however, there is danger of contamination by sewage from the nearby village and already the ection of shellfish is prohibited. Further consideration has, therefore, not been given to the area.

CH ETIVE, ARGYLL

No suitable foreshores were located on the 3 to 4 miles of the southern shore of Loch Etive which e been surveyed. It seems probable that low salinity would also render the loch unsuitable for oysters.

CH SPELVE, ISLE OF MULL

Loch Spelve, a few miles south of Loch Don, has different characteristics. The entrance is narrow shallow but within the loch there is a considerable depth of water. The foreshore is limited in extent the bottom is said to be very muddy (Fullarton, 1891). Both Fullarton and Calderwood (Report in ttish Home Department files) found native oysters on the shores of the loch. The area was not con- red sufficiently favourable to justify an experiment.

E OF SKYE

A survey was made of several parts of the coast of this island, where native oysters are still found ough in small and diminishing numbers. This survey was followed by experimental layings on six unds in 1952. Unfortunately, before results could be obtained the oysters were stolen or removed and the experiments were abandoned. Nevertheless the following localities have been considered.

Caolas Scalpay

The shore surveyed lies between Strollamus in Skye and the south shore of Scalpay Island. Apart m some exposure to the east the area is well sheltered. The beach for a length of at least half a mile sists of pebbles and shells overlying fairly fine grit with some mud. There is little danger of reduced nity because an appreciable tidal stream dissipates the fresh water from the various small streams. danger of pollution exists. Native oysters were still found at the time of the survey from low-water rk up the shore for a distance of 20 to 30 yards. The size distribution of a sample of these oysters wed that a natural spatfall had occurred over several years preceding the survey. This ground would m to be promising and could possibly hold several hundred thousand oysters.

Camus na Sgianadin

This shore lies east of Caolas Scalpay, which it resembles in nature. Shelter is good from almost all ds. Part of the bay consists of gritty sand but a fairly large area of gravelly sand is capable of taking eral thousand oysters. Salinity is little affected by fresh water and there is no danger of pollution. ew native oysters of various sizes were found on the shore.

Loch Ainort

This loch, on the east coast of Skye, is 2½ miles in length, opens to the north-east and is sheltered the Island of Scalpay. Much of the water is deep but there are shallow regions at the head of the

loch and on the south shore at Luib. The bay at the village of Luib has a beach similar to Caolas Scalpa The small stream crossing the shore is unlikely to reduce salinity seriously and danger of pollution fro sewage is slight. Similar small beaches occur along the southern shore of Loch Ainort. The shore at t head of the loch is divided by a river, on the south side of which the beach consists of gravel and de oyster shells with mud in places and on the north side a large expanse of firm gravel. Shelter is adequa but some difficulty may arise from an excess of fresh water, owing to the size of the river and to t narrowness of the loch. The many dead oyster shells of various sizes suggest a considerable populati in the past. Local people say that oysters were removed from Loch Ainort to stock the shore at Strollam A few living oysters were found on the shore. The area, which could carry several hundred thousa oysters, is not recommended owing to the danger of low salinities.

Loch Portree

The southern or inner arm of this loch consists of a large, sheltered bay which almost dries out low water. The bottom varies from soft mud in a few places to a firm shingle and grit extending ov most of the bay. At the southern end the River Varragill crosses the shore, carrying a large volume water. There is little doubt that Loch Portree could carry a large stock of oysters but for the dangers reduced salinity and pollution. Small numbers of dead oyster shells but no living oysters were found the beach.

Loch Snizort Beag

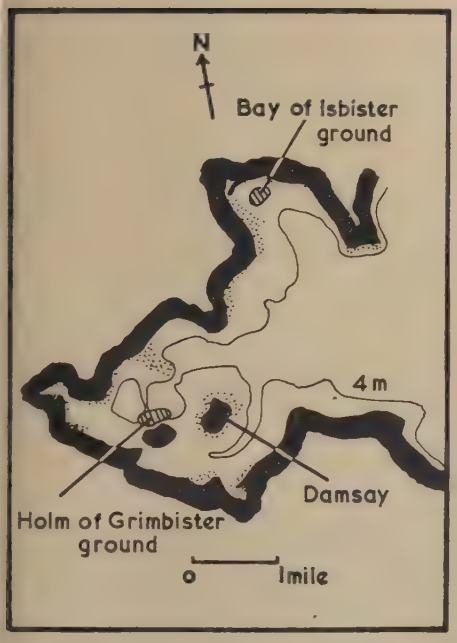
The three lochs at the head of Loch Snizort Beag were surveyed. Little Loch Snizort is a shelter loch with a broad shore exposed at low water. The southernmost part is pebbly and might take oyste From the entrance of the River Tora northwards, however, the shore on the west side of the loch consi of soft, muddy sand, with many *Arenicola*, and is unsuitable for oysters. Dead oyster shells, some of the long and narrow, probably the result of the muddy conditions, were found on the shore. Loch Ey somewhat more open although still adequately sheltered, has a shore of firm fine gravel and sand. stream of moderate size enters the loch but this should not be a serious disadvantage. The ground wou take a considerable number of oysters. Loch Treaslane has at least one area, east of the Treaslane riv with a good, firm shore of shell and pebbles, which should be suitable for relaid oysters. There mig however, be some danger from reduced salinity. Loch Snizort Beag, with its three divisions, would see to be a possible breeding centre. It is sheltered, except from a narrow angle to the north-west, fai shallow, and has pebble and shell beaches on the lower part of which a spatfall might be collecte Successful breeding would depend on suitable hydrographic conditions, especially temperature and tid movements. It is said locally that there used to be quite large oyster beds in Loch Snizort Beag, ow by McLeod of Skeabost House, who employed a watcher to prevent poaching, but whether these be were laid or native is uncertain.

Loch Greshornish

Loch Greshornish is a long, narrow loch opening to the north-east into Loch Snizort and divid at its head into two bays. The bay opposite the village of Edinbain has a shore consisting mainly of sm pebbles overlying grit and is not subject to much wave action. A few *Arenicola* were found above l water mark. The considerable expanse of suitable shore should make it possible to lay oysters far enou from the stream to avoid fresh water. This is one of the most promising shores surveyed in Skye both fattening and possibly for breeding purposes; it could carry several hundred thousand oysters. A f living oysters and many dead shells were found. Several of these were in pairs and had the shells of young oysters attached. Breeding might be revived if the ground were adequately stocked.

Pool Roag

This pool, opening off Loch Bracadale, is almost completely land-locked except for a narrow chan communicating with the main loch. Being well sheltered and shallow it should warm up quickly



. 19 Sketch map of Wide Firth, Orkney, to show degree of shelter, extent of foreshore (stippled) and water of less than 4 m depth. Suitable ground is shown hatched.

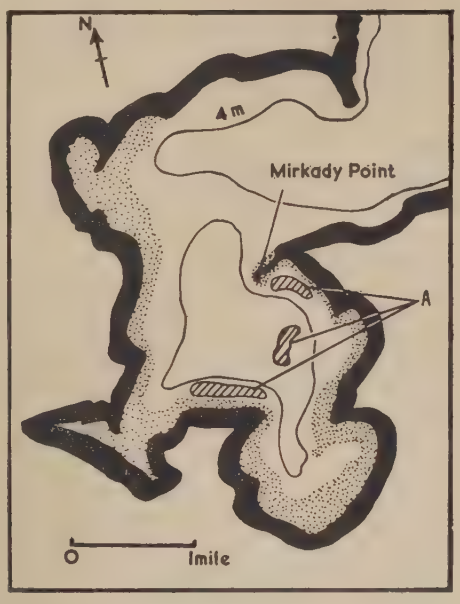


Fig. 20 Sketch map of Deer Sound, Orkney, to show degree of shelter, extent of foreshore (stippled) and water of less than 4 m depth. Suitable ground (A) is shown hatched.

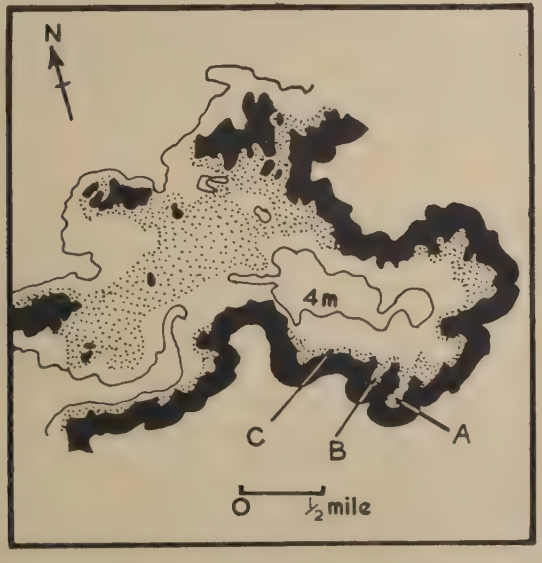


Fig. 21 Sketch map of Arisaig Harbour to show degree of shelter, extent of foreshore (stippled) and water of less than 4 m depth. A, B, C, areas examined in detail.

summer. Unfortunately it was not possible to survey the lower shore, but the bottom appeared to b sandy with areas of shingle. Conditions in Pool Roag might be expected to produce rapid growth an fattening.

Orkney

In 1955 three sub-littoral areas were surveyed in Orkney: the Bay of Isbister, the Bay of Firth an Deer Sound.

Bay of Isbister

This bay is well protected and much of its western part is less than 4 m deep. Only a small amou of fresh water enters the bay; there is no danger from pollution. The substratum is mainly sandy, wit *Arenicola*, but an area near the head of the bay (Fig. 19) consists of clean gravel and coarse grit with litt weed and few stones large enough to interfere with dredging. Here there are about 30,000 sq.yd (25,20 sq.m) of good bottom.

Bay of Firth (Fig. 19)

Shelter is adequate and most of this bay is less than 6 m deep. There is no danger of reduced salinit or of pollution. Much of the bay could not be examined in detail, but in two places, off Damsay and o the north-west point of Holm of Grimbister (Fig. 19), the bottom, consisting of coarse, gritty sand an pebbles, should be suitable for oysters. More ground is probably available in isolated patches free of th reefs which make the Orkney beds difficult to work without an intimate local knowledge of the area It was off Grimbister that the syndicate laid imported oysters the majority of which died in the followin winter (p. 12).

Deer Sound

The inner part of Deer Sound, to the south of Mirkady Point, was surveyed. The area is sheltere and shallow, only a small part exceeding 5 m in depth. A few small streams enter Deer Sound but salinit is unlikely to be seriously reduced; there is no risk of pollution. In the central part of the area at depth greater than 4 m the bottom is generally of soft, black mud unsuitable for oysters, but closer inshore i water of 2 to 4 m depth, considerable areas of mixed sand, grit and broken shell appear suitable for th relaying of oysters. Although only a few areas were sampled it seems likely that much of the coastal stri having depths of 2 to 4 m is of this favourable kind. No experimental layings were made.

Arisaig Harbour, Inverness-shire (Fig. 21)

Arisaig Harbour is a basin about 1 mile long and $\frac{1}{2}$ mile wide communicating with the open se by a narrow channel and well protected by numerous islands and reefs. About half of the basin is less tha 5 m in depth, and fairly large areas of foreshore are exposed at low water. The water in Arisaig Harbou should, therefore, be substantially warmer than the adjacent sea. Neither reduced salinity nor pollutio is a serious risk. A large part of the southern shore was examined and three areas were found with substratum of coarse sand and pebbles suitable for relaid oysters. The bay marked B alone has abou 1,600 sq.yd (1,300 sq.m) of good shore and suitable sub-littoral ground may also exist. The sheltere nature of much of the southern shore is shown by the abundance of *Ascidiella aspersa* in shallow wate extending even to the lower part of the foreshore. The presence of native oysters of various ages show that breeding takes place, and in this area a sufficiently large stock might yield a useful spatfall. N experimental layings were made.

FIELD EXPERIMENTS IN BREEDING

In an oyster fishery it is important to ensure sufficiently frequent and heavy spatfalls to replace rs which have been lifted. On a natural bed, or on one that has been established in a suitable area, replacement results from successful breeding. When natural spatfalls are lacking or insufficient, ever, young stock must either be bought or be produced by some form of artificial breeding. In the nt investigations, therefore, experiments were planned to find if adequate spatfalls would follow the duction of adult stock into a number of selected areas where conditions seemed to favour breeding. sites for these experiments were Linne Mhuirich (Loch Sween), Easdale quarry and West Loch ert. These places appeared to have at least two of the conditions necessary for successful breeding, ely relatively high summer water temperatures and the retention of a high proportion of the water aining the pelagic larvae.

In all the experiments observations were made of water temperature and sometimes of salinity and drogen ion concentration (pH). Temperature was recorded by means of a maximum and minimum nometer, by daily thermometer readings of sea surface temperature or, more generally, by a Cam- ge recording thermometer. Silver nitrate titrations were used in estimating salinity, and a colorimetric od for pH estimation. Oyster larvae in plankton samples were counted and measured to assess l production, mortality and growth. In the early part of the work plankton samples were taken by d hauls with a townet but in most of the investigations quantitative samples were collected using a y pump driven by a petrol engine. Estimations were made of the numbers of organisms in the -plankton, the smaller members of which alone constitute the food of oyster larvae. The method was of direct counting, using a water sample of 7 cu. mm on a Thoma haemacytometer and a low power oscope objective in conjunction with dark ground illumination. The advantages of this method are the organisms are not subjected to the treatment involved in methods of concentrating the sample, that, being quick, it allows replicate counts to be made conveniently. The main disadvantage is it does not allow identification or even classification of the organisms, except roughly into size ps.

The author wishes to thank Mr. J. N. Thomson, Mr. B. T. Hepper, Dr. A. D. Ansell, Dr. J. A. , Dr. R. B. Clark, and Captain R. Walker, O.B.E., for assistance at various stages of this work.

E MHUIRICH, LOCH SWEEN (Fig. 18)

The site chosen for these experiments, Linne Mhuirich, is a branch of Loch Sween, Argyll. It is t $2\frac{3}{4}$ miles long and varies in width from $\frac{1}{8}$ to $\frac{1}{4}$ mile. For a distance of one mile from the head of the the water is less than 3 m in depth while the rest of the inlet is generally less than 6 m. A narrow ow mouth with a marked sill leads to the main body of Loch Sween.

ides

The vertical tidal range is small within Linne Mhuirich. This has been recorded by Lewis and ell (1960) as about 2·2 ft on a day of spring tides, while the greatest range noted during a period alm weather from 10th to 19th September, 1958, was 2·8 ft (Dr. C. H. Mortimer, personal munication). Although the range is certainly small it is affected by the prevailing weather. Thus the may remain almost at full or almost at ebb for periods extending sometimes to several days, rding to the strength and direction of the wind. This feature and the limitations of suitable ground to rrow zone immediately below low-water mark constitute a danger since prolonged low-water may se the oysters for excessive periods to frost or strong sunshine. This danger is referred to by Malcolm 4) who stated that frost killed many of the young, and also some older, oysters when north and east ls drove the tide down for a longer period than usual.

Substratum

Shallow sub-littoral ground, suitable for oysters, is limited round the shores of Linne Mhuirich over a great part of the inlet a steep bank of boulders leads to soft black mud immediately off-shore. However, shallow water with a firm bottom of coarse sand and grit occurs on the western shore near Dun Mhuirich and on a narrow strip of the upper mile of the inlet.

Existing stock of oysters

When experiments were started only a few oysters were found in the course of extensive surveys of the shore and shallow water. These oysters were natives in the sense that they had settled from larvae produced in the loch. Genetically, however, they perhaps did not represent a continuation of the aboriginal stock, since importations of French oysters had been made during the 19th century and crossing probably occurred.

The experiments

Dr. Marshall and Dr. Orr, who had laid oysters and found that they grew well in certain parts of Loch Sween, made preliminary observations of spatfall in this area, but were unable to follow the course of breeding. Following the establishment of a field station in 1946, detailed observations were made by Dr. R. B. Pike, Mr. A. D. McIntyre and the author in 1947 and by the author and Mr. J. N. Thomas in 1948. In 1946 the work was concerned with setting up the field station, establishing a breeding stock of oysters, experimenting with different kinds of spat collector and making observations on temperature and larval production. The breeding stock was increased in 1947 by a few thousand and was then accommodated in a series of wire-bottomed containers to prevent the oysters being buried in sand.

Water temperature

During much of June and July 1946, the surface temperature varied from 15·0 to 19·0°C, occasionally rising above 20·0°C, and in August from 16·0 to 18·0°C (Fig. 22). Water temperatures were far less satisfactory during the summer of 1947, remaining above 15·0°C during the second half of June, only

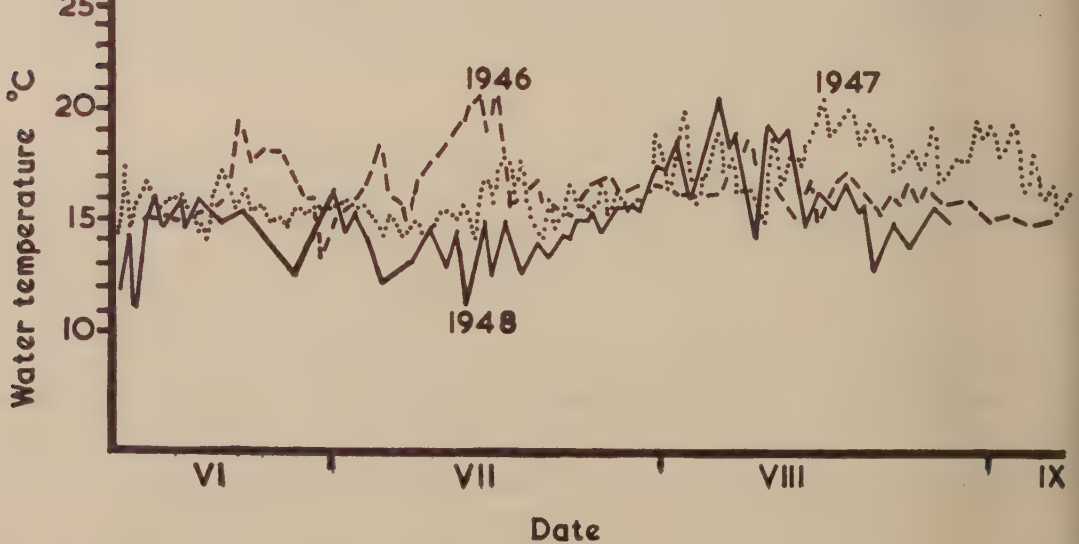


Fig. 22 Sea surface temperature in Linne Mhuirich in June-September, 1946, 1947 and 1948.

C in the second half of July, and over 18·0°C for much of August. In 1948 temperatures in the first f June rarely exceeded 15·0°C; in July they ranged from 14·0 to 16·0°C and in August from 14·0 ·0°C. The records of these three summers suggest that the water temperature in this inlet is much e that of adjacent coastal waters, and is thus favourable to the breeding of oysters.

inity

Inspection of maps and a survey of the site showed that the drainage area affecting Linne Mhuirich all, so that little fresh water enters the loch. It was, therefore, considered unnecessary to make ne measurements of salinity, which was assumed to be always at a safe level.

ts

Ascidiella aspersa is common in Linne Mhuirich where it was found that 'Tufnol' plates, hung in vater to catch oyster spat, soon became completely covered with the ascidian. It was, accordingly, sary to investigate the breeding and settling period of this animal which must be regarded as a in the area. Preliminary observations in 1947, in which larvae of *A. aspersa* were counted in the kton samples, showed that the ascidians bred at the same time as the oysters. In 1948 many eggs and e were already present when the first sample was taken on 26th May. Thereafter the numbers nated but eggs or larvae were present in all samples up to 26th August, when observations ended 23). 'Tufnol' plates hung in the water on 19th June quickly acquired a coating of young ascidians. number settling on an area of 4·8 sq.cm weekly varied up to a maximum of 630 in the week ending uly, while the mean over the period was 208. Growth of the ascidians was so fast that, by the beginning ugust, individuals 6 weeks old had already reached a length of 2·5 cm. The density of settlement speed of growth of *A. aspersa* on objects hung in the water ensured that oyster larvae either failed to or, having settled, were quickly overgrown by the ascidians throughout the whole breeding season e oysters.

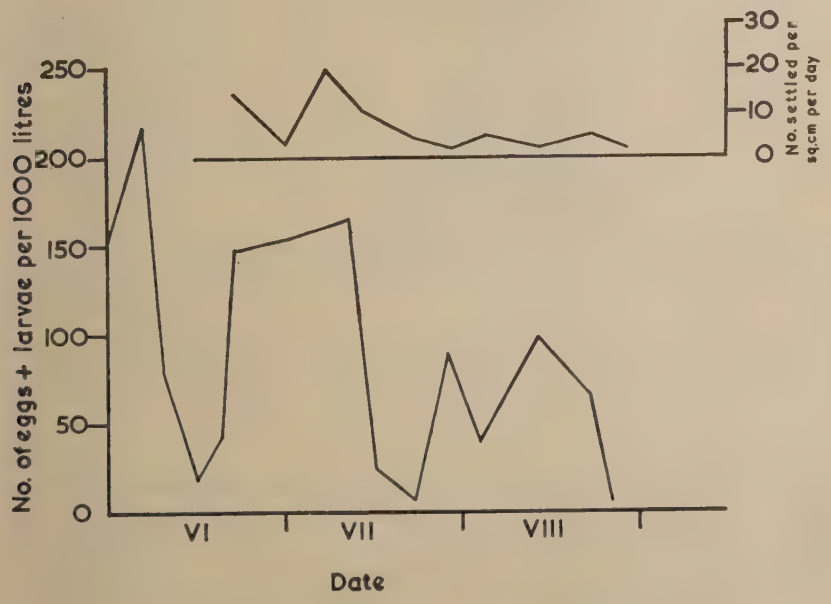


Fig. 23 *Ascidiella aspersa* (Müller) in Linne Mhuirich. Numbers of eggs and larvae in 1000 litre water samples, and numbers of larvae settled per day per 1 sq. cm of an experimental 'Tufnol' plate hung in the water.

Breeding of oysters

In 1946 oyster larvae were produced in moderate numbers and at times showed good gro Despite evidence of a light settlement the spatfall was obscured by *Ascidiella aspersa*. In 1947, stanc 10 minute hauls were made with a townet pulled by a small boat rowed at a uniform speed. The met is not quantitative; results are comparable within the season 1947, but not with results from pi samples taken in 1948. The details for 1947 are shown in Table XI. Larvae appeared in the sample 25th June and reached a first maximum on 27th June. Subsequent maxima occurred about 7th 24th July after which only small liberations were recorded and towards the end of August very few la were found. Good larval growth occurred about the middle of July, but the size of the resultant spa could not be measured as the experimental surfaces were again seriously fouled by *A. aspersa*. In 1

TABLE XI

LINNE MHUIRICH; NUMBER AND SIZE OF OYSTER LARVAE IN 10-MINUTE TOW NET HAULS IN 1947 (E DENOTING EYED LARVAE)

Date	Percentage distribution by size (mm)								No. of larvae per 10-minute haul
	0·16	0·18	0·20	0·22	0·24	0·26	0·28	0·30	
25.6.47	–	–	100	–	–	–	–	–	2
27.6.47	5	63	30	2	–	–	–	–	82
1.7.47	–	4	44	44	6	2	–	–	67
4.7.47	–	14	72	14	–	–	–	–	7
7.7.47	–	43	44	5	4	2	2	–	96
11.7.47	–	27	41	9	9	9	5	–	22
14.7.47	9	37	45	1	6	1E	1E	–	67
17.7.47	–	58	37	–	5	–	–	–	27
21.7.47	–	27	46	20	7	–	–	–	32
24.7.47	2	38	56	4	–	–	–	–	150
29.7.47	–	27	50	16	7	–	–	–	61
1.8.47	–	23	52	17	8	–	–	–	17
5.8.47	–	31	37	24	4	4	–	–	29
8.8.47	–	–	100	–	–	–	–	–	3
11.8.47	–	67	33	–	–	–	–	–	3
15.8.47	–	–	–	–	–	–	–	–	0
17.8.47	–	67	33	–	–	–	–	–	3

TABLE XII

LINNE MHUIRICH; NUMBER PER 1,000 LITRES, AND SIZE OF OYSTER LARVAE IN 1948

Date	Percentage distribution by size (mm)							No. of larvae per 1,000 litres
	0·18	0·20	0·22	0·24	0·26	0·28	0·30	
4.6.48	–	70	30	–	–	–	–	7
9.6.48	17	33	33	17	–	–	–	6
14.6.48	40	60	–	–	–	–	–	5
17.6.48	–	–	50	50	–	–	–	2
21.6.48	50	25	–	–	25	–	–	4
1.7.48	9	64	18	6	0	3	–	33
7.7.48	38	40	7	10	5	–	–	95
14.7.48	12	51	31	6	–	–	–	35
22.7.48	–	100	–	–	–	–	–	3
28.7.48	38	60	2	–	–	–	–	50
4.8.48	33	67	–	–	–	–	–	6
11.8.48	52	48	–	–	–	–	–	73
19.8.48	83	17	–	–	–	–	–	6
26.8.48	–	100	–	–	–	–	–	1

r larvae were present in all quantitative pump samples from 4th June to the end of August when vations ended. Larval production was greatest in July and in the first half of August. Larval growth best in the latter half of June and in the first week of July, a small percentage of the larvae then ning settling size (Table XII).

he value of Linne Mhuirich as a breeding place

Expectations that physical conditions would be suitable for breeding in Linne Mhuirich have been rmed. In particular, the temperature of the water, which during the summer was generally higher that of the adjacent open coast, often by several degrees, encouraged the satisfactory production growth of larvae. Direct observation of spatfalls was obscured by settlement of *Ascidiella aspersa*, there is reason to believe that some spatfall occurs in most years. This is based on the presence of larvae in the years when samples were taken and on the structure of the oyster population shown by rvey in 1957. The size distribution of all oysters found during the survey is shown in Fig. 24. It is ent that several settlements are represented and the following conclusions may be drawn. In 1957 spatfall was light; there is no evidence of a settlement in 1956 but it may have been too small to be cted in the sample; in each of the years 1955 and 1954 one spatfall occurred; in earlier years there settlements which cannot be separated into year classes. It is also obvious that a larger stock of ng and half-grown oysters was present in Linne Mhuirich in 1957 than at the beginning of the riments in 1946. This increase can reasonably be attributed to the breeding during the three years riment of the introduced stock of oysters, which was probably larger than the remaining native k and situated in a favourable place. The conclusion is, therefore, that Linne Mhuirich has the sical and biological conditions necessary for successful breeding.

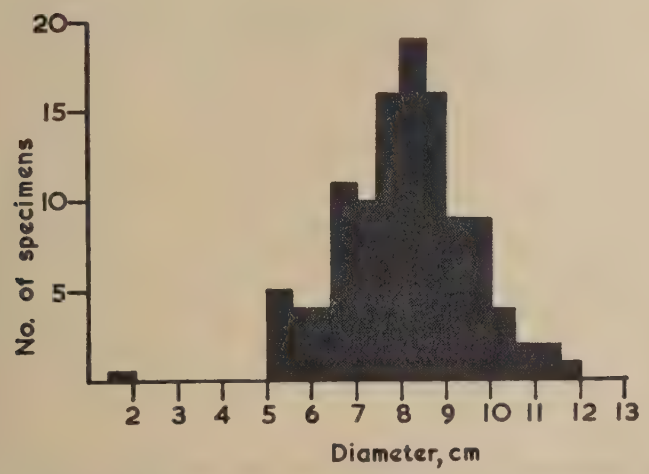


Fig. 24 Linnhe Mhuirich. Size-distribution of oysters in 1957.

Other factors must be considered, however. The presence of large numbers of *A. aspersa* might be ected to reduce the numbers of spat that could be collected if the area were developed as a breeding tre. But oysters were commonly found on living and dead mussel shells and on other sea-floor objects which *A. aspersa* was scarce. It seems, therefore, that although settlement surfaces hung in mid-water quickly rendered useless as spat collectors, culch laid on the bottom in shallow water will remain ilable to oyster larvae. A further consideration, and perhaps a more serious one, is the relatively ll area of bottom on which stock could be laid. By careful use of all the suitable ground at least a lion oysters could be accommodated; it has been reported that the former oyster fishery in Linne uirich had at one time 3 million oysters. A breeding stock of this size should provide satisfactory

spatfalls if other measures, particularly the laying of sufficient culch on the bottom, are taken to sec it. Linne Mhuirich is, therefore, regarded as a possible site for oyster breeding and the production spat.

Easdale

On Easdale Island, Argyll, there are several disused slate quarries which have been flooded by sea. A preliminary survey of these quarries was made by Dr. Marshall and Dr. Orr and a hydrograp survey by Dr. H. D. Slack. As a result it was decided to use one of the quarries for breeding experimer This quarry has a surface area of 4,580 sq.m, a mean depth of 14 m and a volume of about 70,000 cu. The salinity during the survey was 20·4‰ at the surface and 21·3‰ at 19 m. These salinities, altho not lethal to oysters, are much below optimal requirements so a channel was cut from the quarry to sea to allow sea water to enter at high tide. As a result the salinity rose considerably during the win but rather less in the summer; by the beginning of the breeding experiments, in June 1948, it had reac 24·5‰, a value still low, but considered safe.

The breeding oysters could not be placed on the bottom owing to the depth of the quarry; inste they were contained in wire cages hung from buoys. In 1948 the stock comprised 775 four-years-old a 1,320 two- or three-years-old Brittany oysters. It was impossible in 1948 to visit the experiment m than once or twice each week during the breeding season but in 1949 a field station was set up, allowi more detailed observations to be made, particularly on the nanoplankton, which was not studied in previous year. About the same number of oysters was used as in 1948.

Water temperature

In 1948 (Fig. 25) the temperature at 2 m remained above 15·0°C during the second half of J and the first week of August and at the surface above 16·5°C during most of the period. At 2 m, wh the oysters were placed, the temperature exceeded 17·0°C for only a few days at the beginning of Augu

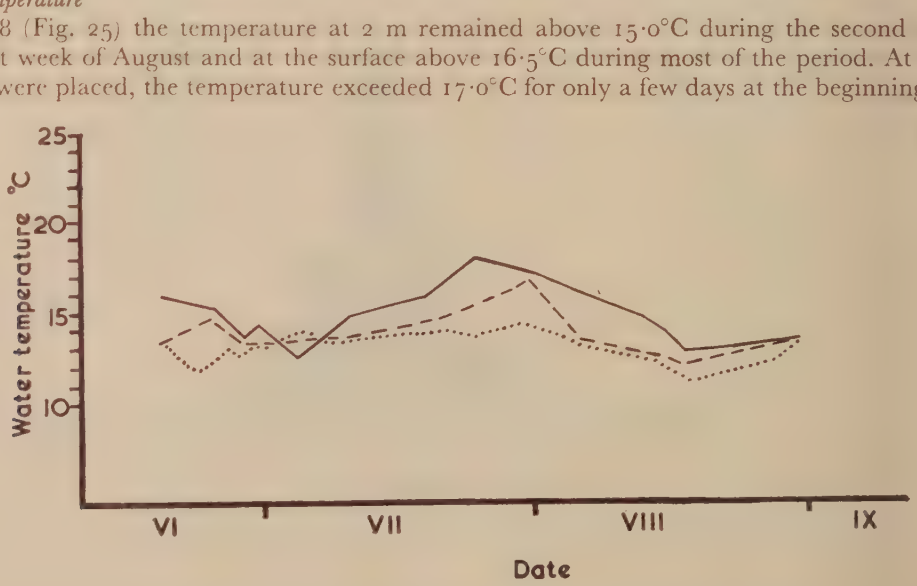


Fig. 25 Water temperature (°C) in Easdale Quarry, June-August, 1948. ———— surface, - - - - - 2 m, ... 5 m

In 1949 (Fig. 26) the temperature at 2 m was over 15·0°C from 18th June to 17th September, o 17·0°C from 22nd June to 31st July, over 18·5°C from 24th June to 14th July and over 19·0°C from 2 June to 5th July. Thus in 1948 the temperature was fairly satisfactory but not sufficiently high to prom large-scale breeding and rapid larval development. In 1949, a warm summer, the temperature was m favourable.

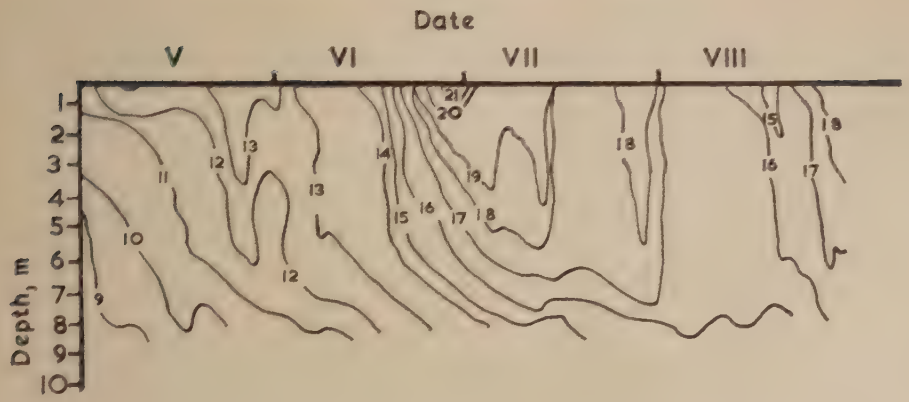


Fig. 26 Water temperature (°C) in Easdale Quarry, May-August, 1949.

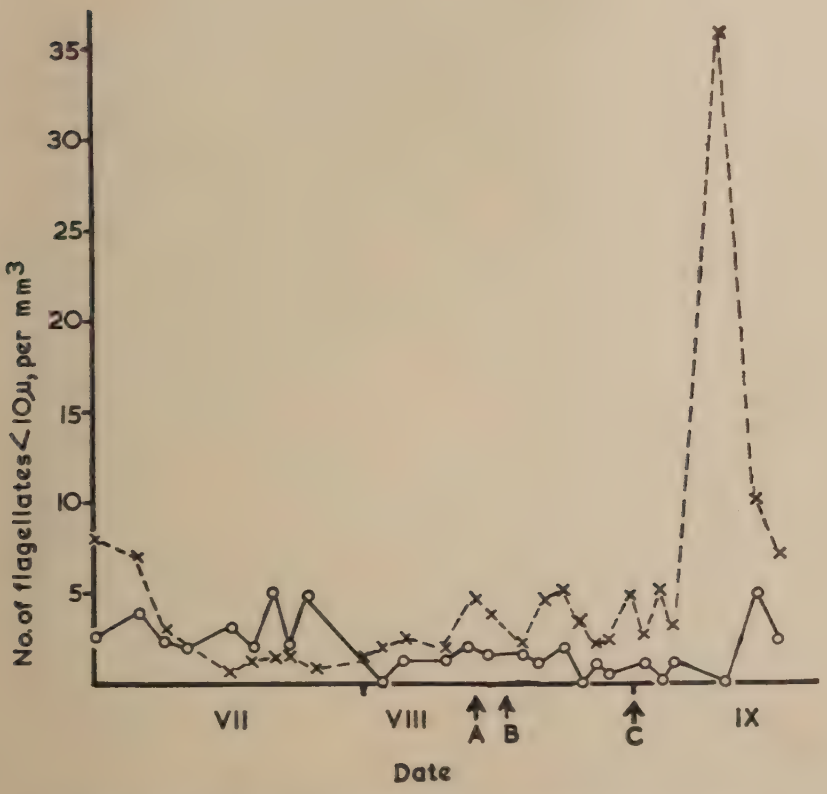


Fig. 27 Nanoplankton in Easdale Quarry in 1949. Number of flagellates per mm^3, of 3-10μ diameter (o——————o) and under 2μ diameter (x - - - - - - - x). Arrows show times of addition of nitrate (A) and superphosphate (B, C).

Salinity

The salinity during most of the summer of 1948 was 24·5‰, and in 1949 30·0‰. Although 24·
would generally be considered too low for successful breeding, larvae were produced, grew to full s
and settled at this salinity.

Hydrogen ion concentration (pH)

No danger arose from high values of pH, as corrected readings rarely exceeded 8·2 at a depth
2 m, and only once, after the addition of fertilisers, reached 8·4.

Nanoplankton

No estimates were made of the nanoplankton in 1948. In 1949 counts were made at intervals
or 3 days (Fig. 27) when it was found that flagellates under 10 μ in diameter, that is, those which can
eaten by oyster larvae, generally numbered 5-10 per cu.mm, but often were fewer than 5 per cu.mm.
these flagellates many were probably of little food value to the larvae and it seemed that food was scar
Efforts were made therefore to increase the numbers of flagellates by adding artificial fertilisers to
water of the quarry.

Experiments with fertilisers

On 19th August 2 cwt of sodium nitrate was added to the water and on 20th August $\frac{1}{2}$ cwt of 18
superphosphate. On 22nd August, when the water appeared noticeably greenish, a marked increa
was observed in the number of diatoms, an increase which was maintained until 25th August. The n
motile algae started to increase about 27th August, reached a maximum on 30th August and declined
about their pre-fertilisation level by 1st September. No appreciable increase in flagellates followed t
addition of fertilisers. On 1st September a second application of 18% superphosphate ($\frac{1}{2}$ cwt) was ma
By 6th September the water had become brownish in colour, owing to the presence of numbers of
unidentified green-brown flagellate about 15 μ long. This species continued to increase until 13th Septem
then gradually decreased. On 12th September a green coating appeared on the stones round the sho
of the quarry, caused by the presence of green algae resembling *Carteria* in a non-motile phase. In addit
a remarkable increase took place in the numbers of flagellates of about 2 μ in diameter, which reach
a maximum of 40 per cu.mm on 10th September. These small flagellates included at least two speci
whose relative abundance fluctuated. Following the first fertilisation the corrected pH rose shar
from 7·95 to 8·20 in three days and, following the second fertilisation, it rose from 8·14 to 8·40 in thirt
days. The effects on the phytoplankton of the two applications of fertilisers were thus different. The fi
application, of nitrate and superphosphate, resulted in an increase in diatoms but little change in t
number of flagellates. The second application, of superphosphate alone, was followed by little cha
in the diatom population but by a marked increase in the numbers of various flagellates. It is not su
gested that in the two cases the different changes in composition of the phytoplankton resulted simp
from the different chemical nature of the fertilisers; nor is it at present possible to predict which eleme
of a changing phytoplankton might increase after the addition of a particular chemical. It is evide
however, that important changes in the phytoplankton can be produced in an enclosed body of wa
by the addition of chemical fertilisers, although Waugh (1957) found only a slight increase in nan
plankton in an Essex creek after fertilisation.

Numbers and growth of larvae in 1948 (Table XIII)

In 1948 oyster larvae were present from 22nd June until 2nd September. The maximum record
concentration was 1·85 per litre on 9th August. On most occasions greater numbers of larvae we
found at a depth of 0·5 m than at a depth of 4·0 m. From 28th July to 9th August, a small proportion
the larvae measured 0·28 mm or more; most of these were eyed.

Table XIII

EASDALE QUARRY; NUMBER PER 1,000 LITRES AND SIZE OF OYSTER LARVAE IN 1948 (E DENOTING EYED LARVAE)

Date	Percentage distribution by size (mm)							No. of larvae per 1,000 litres
	0·18	0·20	0·22	0·24	0·26	0·28	0·30	
28.6.48	–	33	59	8	–	–	–	Unknown
30.6.48	–	–	50	50	–	–	–	2
6.7.48	4	86	8	–	2	–	–	47
13.7.48	70	30	–	–	–	–	–	31
20.7.48	20	58	16	6	–	–	–	520
28.7.48	–	45	10	25	10E	10	–	9
4.8.48	14	38	33	12	1	1E	1E	358
9.8.48	26	70	1	<1	<1	<1E	–	1,850
18.8.48	76	21	–	–	3	–	–	290
24.8.48	43	57	–	–	–	–	–	7
2.9.48	2	50	46	0	2	–	–	36

Table XIV

EASDALE QUARRY; NUMBER PER 1,000 LITRES AND SIZE OF OYSTER LARVAE IN 1949 (E DENOTING EYED LARVAE)

Date	Percentage distribution by size (mm)							No of larvae per 1,000 litres
	0·18	0·20	0·22	0·24	0·26	0·28	0·30	
17.6.49	100	–	–	–	–	–	–	5
23.6.49	–	67	33	–	–	–	–	7
27.6.49	–	46	50	4	–	–	–	105
29.6.49	–	11	17	41	26	5	–	14
1.7.49	–	76	21	3	–	–	–	120
4.7.49	–	2	63	33	2	–	–	500
6.7.49	–	52	38	10	–	–	–	30
8.7.49	50	–	25	25	–	–	–	5
11.7.49	41	33	26	–	–	–	–	11
13.7.49	26	54	13	7	–	–	–	250
15.7.49	44	30	15	4	7	–	–	34
18.7.49	17	83	–	–	–	–	–	195
20.7.49	38	62	–	–	–	–	–	226
22.7.49	50	50	–	–	–	–	–	27
25.7.49	50	43	7	–	–	–	–	30
27.7.49	62	23	15	–	–	–	–	13
29.7.49	100	–	–	–	–	–	–	53
1.8.49	100	–	–	–	–	–	–	481
3.8.49	72	28	–	–	–	–	–	113
5.8.49	94	6	–	–	–	–	–	27
9.8.49	73	23	4	–	–	–	–	29
12.8.49	34	59	7	–	–	–	–	103
15.8.49	31	65	4	–	–	–	–	36
17.8.49	56	15	29	–	–	–	–	62
19.8.49	70	20	–	10	–	–	–	9
24.8.49	31	55	6	7	1	–	–	101
26.8.49	47	47	4	2	0·001E	0·001E	–	1,230
29.8.49	25	33	29	10	3	0·01E	–	94
31.8.49	15	60	14	6	5	0·005E	–	229
2.9.49	18	72	7	–	–	3E	–	30
5.9.49	50	50	–	–	–	–	–	2
7.9.49	81	16	2	1	–	–	–	124
10.9.49	67	33	–	–	–	–	–	15
12.9.49	30	70	–	–	–	–	–	16
14.9.49	6	36	58	–	–	–	–	19
16.9.49	100	–	–	–	–	–	–	4

Spatfall in 1948

Unglazed porcelain saucers, hung at various depths, were provided for larvae to settle on. Oyste spat were first seen on 10th August and a light spatfall resulted from the eyed larvae observed fro 28th July to 9th August. The average number was one spat per saucer (area 380 sq.cm). The occurrenc of only one spatfall in 1948 was confirmed from the analysis of the sizes of partly grown spat by the us of probability paper (Harding, 1949). Spat were collected on cemented cardboard egg-box-fillers an asbestos sheets hung in the quarry, and the growth of these spat is dealt with later (pp. 52-53).

Numbers and growth of larvae in 1949 (Table XIV)

The production of larvae in 1949 was on the whole rather less than in 1948, with a smaller maximu production. During three periods (23rd-29th June, 8th-15th July, and 24th August-2nd Septembe larvae grew to settling size, but only on the last of these occasions were eyed larvae seen. No obviou correlation could be found between successful growth of larvae and the numbers of flagellates whic might serve as food.

Spatfall in 1949

Few spat were detected soon after settlement, but later analysis of the size of partly-grown spa indicated that there had been some spatfall in each of the three periods of successful growth alread noted. Approximately 5% of the total spatfall occurred at the end of June, 22% in the middle of Ju and 73% at the end of August, these figures being obtained by the use of probability paper (Hardin 1949).

Larval production

Production of larvae in the Easdale quarry can be compared with the production in the tanks Conway (Cole, 1939) and in the oyster poll at Flødevig (Fagerland, 1945). By reducing the stock in eac case to a standard of 600 oysters and the volume of water to a standard of 5,000 cu.m, the followin comparable figures are obtained.

	Mean number of larvae/10 l.
Conway - -	125
Flødevig -	200
Easdale - -	16

These figures, although approximations, indicate that the Easdale quarry, during 1949 at leas was very much less efficient in the production of larvae than either Conway or Flødevig.

Experiments in 1950 and 1951

Experiments at Easdale were limited in 1950 and 1951. Breeding stock and cemented egg-box fill were placed in the quarry as in 1948 and 1949 and a few visits paid during each summer but no spatf was found in either 1950 or 1951.

The value of the Easdale quarry as a breeding place

Of the four years in which experiments were carried out, one showed a light spatfall, one a tra and the remaining two no spatfall that could be detected. One summer was of mixed weather, one h and dry and two rather cold and wet. It is, therefore, reasonable to conclude that, in the absence techniques to control physical and biological conditions in a large body of water, the results for the four years represent a fair sample of results to be expected over long periods. Easdale quarry must classified as an unsuitable place for producing oyster spat, although occasional slight spatfalls may obtained.

Growth of spat in Easdale quarries

The oyster spat obtained from the breeding experiments in 1948 and 1949 and grown in two of t

ded quarries were measured at intervals in order to assess the suitability of the quarries for growing to a size at which they can be laid on the shore. In 1948, spat obtained in the breeding quarry were nsferred when about a month old to an adjacent tidal quarry where they were grown in wire cages g from the side of the quarry at a mean depth of 1 m. The 1949 spat were left in the breeding quarry,

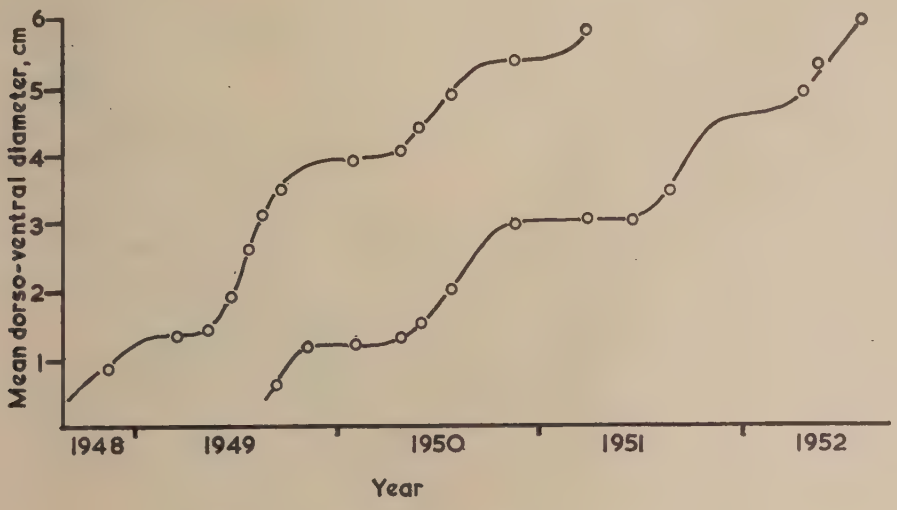


Fig. 28 Growth of spat in Easdale Quarries.

attached to asbestos sheets on which they had settled. Fig. 28 shows the mean dorso-ventral diameter (1) 1948 spat grown in the tidal quarry, and (2) 1949 spat grown in the breeding quarry. By the end ne 1949 growing period the spat which settled in late June were three times the diameter of the spat ch settled in late August. The considerable advantage of an early spatfall is thus obvious. Three clusions may be drawn from the observations:

(1) in both quarries growth of spat started each year about May and continued until autumn;
(2) at about 2½ years of age many oysters were large enough to be laid on sheltered shores for further growth;
(3) the mortality was not heavy.

st Loch Tarbert (Fig. 29)

Details of this loch have already been given (p. 25). Most of the water is shallow: in the upper iles the depth rarely exceeds 7 m, and much of the seaward half is less than 16 m deep. The nature ne bottom varies considerably, from soft black mud in the central trough to firm sand on the coastal f. The tidal range is small and tidal currents are scarcely perceptible over most of the area.

West Loch Tarbert seems to have the right ecological conditions for oysters besides being fairly e to possible markets. The former existence of a native stock of oysters and of a fishery also indicate suitability of the area. This place therefore was chosen as the site of the third field experiment, mainly cerned with breeding. Detailed observations were made in 1955, 1956 and 1957.

unshine

Table XV shows the mean daily hours of bright sunshine which were estimated during each summer provide a rough indication of whether the season was below, about, or above, average. Sunshine was ve average in 1955 and below average in the other years.

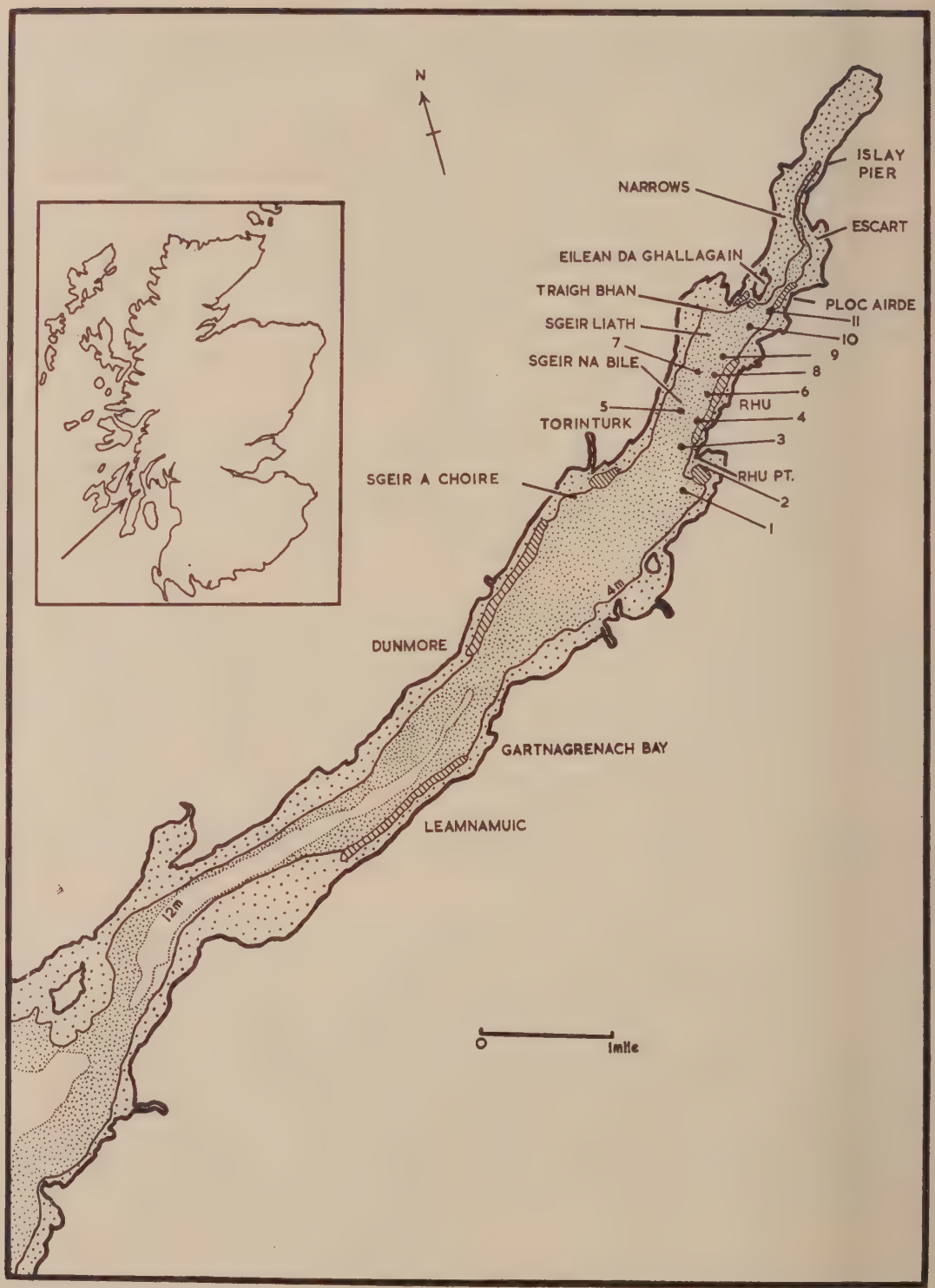


Fig. 29 Sketch map of West Loch Tarbert. Suitable grounds are shown hatched. Numbers 1-11 indicat stations where pump samples were taken for recovery of stained larvae.

TABLE XV

ESTIMATED MEAN DAILY HOURS OF SUNSHINE AT WEST LOCH TARBERT

	1955	1956	1957
May	7·85	–	–
June	3·73	–	–
July	7·97	3·6 (period 14th–31st)	4·3
August	6·0	4·8	4·8 (period 1st–18th)

ainfall

A standard gauge was used to measure rainfall; the figures in inches for the monthly totals are n in Table XVI. These figures confirm the general picture of the seasons as given by the records unshine.

TABLE XVI

RAINFALL, IN INCHES, AT WEST LOCH TARBERT IN THE SUMMERS OF 1955, 1956, 1957, AND MEAN AT MILLPORT FOR PERIOD 1916-1954

	1955	1956	1957	Mean for period 1916–1954 (Millport)
June	3·32	–	–	2·72
July	1·75	2·84 (period 16th–31st)	11·28	3·44
August	1·53	–	2·25 (period 1st–18th)	3·78

ind

Only rough estimates were made of the strength and direction of the wind. Table XVII shows little wind was experienced during the summer of 1955, but that winds were considerably stronger 956 and especially in 1957.

TABLE XVII

ESTIMATED WIND AT WEST LOCH TARBERT

	No. of days with light or no wind			No. of days with moderate or strong wind		
	1955	1956	1957	1955	1956	1957
June	25	–	–	5	–	–
July	31	11 (period 14th–31st)	13	0	7 (period 14th–31st)	18
August	28	19	5 (period 1st–18th)	3	12	13 (period 1st–18th)

ater temperature

Records of the sea temperature were obtained by means of a recording thermograph, a reversing nometer and an ordinary thermometer for surface readings. The thermograph was placed on the

shore of Eilean da Ghallagain, as near as possible to one of the oyster beds, with the bulb 15 cm off t bottom and covered by about 60 cm of water at low tide. Fig. 30 shows the sea temperatures during t periods of observation in 1955, 1956 and 1957. The temperatures in 1955 were satisfactory for breedi in 1956 unsatisfactory and in 1957 moderately suitable. It is probably safe to conclude that in go summers the water temperature is between 17 and 20°C for a considerable part of the time and in po summers between 13 and 16°C. A fair proportion of summers is therefore likely in which temperatu favour satisfactory production, survival and growth of larvae.

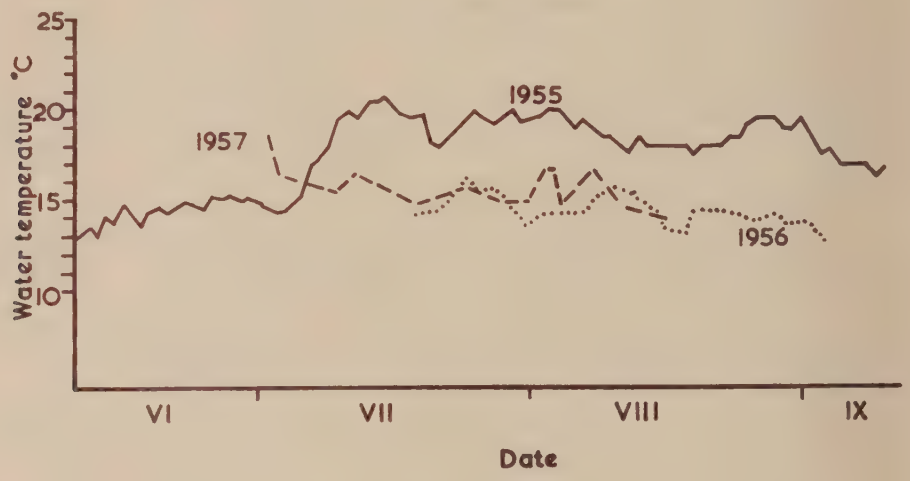


Fig. 30 West Loch Tarbert. Sea temperature 1955 (—————), 1956 (. . . . .) and 1957 (— — —).

Salinity

There is a danger of reduced salinity near the head of West Loch Tarbert after heavy rain. example, the total rainfall of 1·38 in. on 28th and 29th June, 1955, resulted in the salinity measureme of 30th June, shown in Table XVIII. From 9th to 15th July, 1956, the rainfall was 4·68 in., and 23rd July, 1956, 1·22 in. of rain fell. Measurements on 16th and 24th July gave the result shown Table XIX

On each of these occasions water of greatly reduced salinity was confined to the surface layers; on bottom near the adult oysters the reduction was relatively small. Such conditions, therefore, do endanger the adults. Larvae might suffer from the occasional presence of large amounts of fresh wa in the surface layers, but this is unlikely to be a serious factor during most of the breeding season.

TABLE XVIII

SALINITIES IN WEST LOCH TARBERT ON 30TH JUNE, 1955

Depth (m)		0	0·5	1·0	2·0	3·0	4·0
Salinity ‰	Islay Pier	8·6	29·7	30·5	31·4	32·1	32·6
	Eilean da Ghallagain	20·2	–	28·7	–	–	32·6
	Rhu	25·2	–	30·2	–	–	32·7

TABLE XIX

SALINITIES ‰ IN WEST LOCH TARBERT ON 16TH AND 24TH JULY, 1956

Depth (m)		0	1·0	2·0	3·0	4·0	5·0
	Date						
Islay Pier	16.7.56	23·9	31·6	31·9	32·1	–	–
	24.7.56	12·6	–	–	–	–	–
Between Islay Pier and Narrows	16.7.56	22·9	31·6	32·0	32·5	–	–
	24.7.56	10·4	29·4	32·8	–	33·3	–
Escart Bay	16.7.56	28·9	31·3	32·1	32·6	–	–
	24.7.56	12·2	30·3	32·7	33·6	–	–
Eilean da Ghallagain	16.7.56	29·1	30·2	30·2	33·5	–	–
	24.7.56	20·1	30·4	32·9	33·7	33·2	–
Rhu	16.7.56	30·5	31·0	32·0	–	–	32·7
	24.7.56	29·7	32·0	33·5	33·6	33·6	

Tides

West Loch Tarbert has a small tidal range, which is given in the West Coast of Scotland Pilot as ft at springs and 2·1 ft at neaps and on Admiralty Chart No. 2477 as 4 ft at springs. In addition to small range there are other tidal peciliarities within the loch. For a long period in each cycle the is approximately full and for another long period it is approximately low, with correspondingly rt periods of flood and ebb. Moreover, both the rise and the fall are interrupted by small reverse vements. Fig. 31 represents a typical set of readings made on a tidal pole during calm weather. The

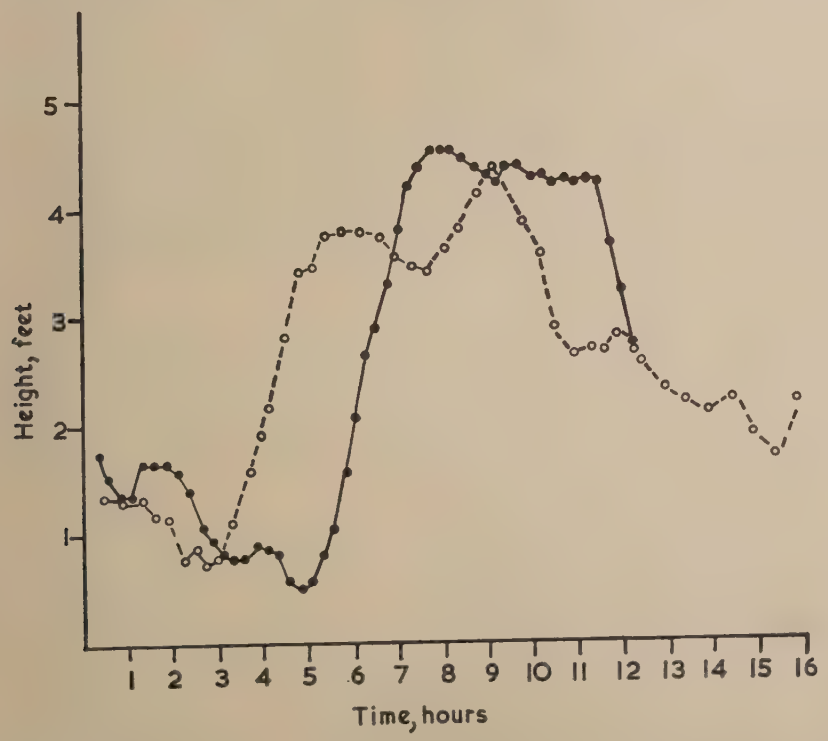


Fig. 31 West Loch Tarbert. Water level in tidal cycle during two days of calm weather.

significance of the long period of low water for oyster culture is the interruption of feeding and the dang of excessive exposure to heat or cold which would be experienced by oysters on the foreshore. The tid streams are, in general, weak. According to the West Coast of Scotland Pilot the ingoing stream springs measures 0·8 knots and the outgoing stream at springs 1·4 knots, at the mouth of the loch. With the loch the streams are "barely perceptible". In order to investigate the tides simple drift kites we made and liberated in fleets at various points in the upper reaches of the loch and at various states the tide. It would need a much more detailed study to discover the general pattern of water movemer within the loch, but certain important features have emerged. The results indicate that, even at spri tides, the tidal streams are weak in the upper part of the loch. The greatest distance covered by a dr kite was about half a mile, during ebb tide. This movement was made almost entirely in $3\frac{1}{2}$ hou representing a mean speed of 0·14 miles per hour. During the same period other kites released at t same time but at different places covered much shorter distances so that the mean tidal speed over t whole cross section of the loch is probably less than 0·1 mile per hour in the upper reaches of the inl Tidal movements are far from uniform across the loch, both in speed and direction, and it can happ that, while water at one side is moving towards the head, water on the other side is moving towards t mouth. No residual movements of water into or out of the loch were observed, but these would ha escaped detection by the method used, and are likely to be slight.

Water movements are important in relation to the dispersal of oyster larvae during their pela life. Such information as was obtained in the foregoing experiments might have suggested relativ small movements along the length of the loch. However, the experiments with stained living larv described elsewhere (p. 66), show that this is not so, and that larvae liberated, for example, on t beds at Rhu are subsequently dispersed over at least $1\frac{1}{4}$ miles in 18 hours. In the absence of any eviden of directional swimming by the larvae, this dispersal implies considerable mixing of the water by t action of tidal streams. Although a satisfactory proportion of larvae is retained within the loch, th larvae must move passively for long distances up and down the loch before reaching settling size.

Substratum

In general the bottom in areas more than 4 m deep consists of soft black mud; in areas of less th 4 m depth it usually consists of a variable but firm mixture of sand and mud, but in sheltered places the same depth the substratum is soft. Analyses of bottom material are shown in Fig. 32. The bottom the entire central, deeper part of the loch is unsuitable for oysters and all the good ground is confin to the shelf round the shores (Fig. 29). Not all of this coastal area is suitable, however, as in some pla the numerous *Arenicola marina* tend to bury the oysters and to interfere with dredging by rendering t bottom uneven.

Area available

The area available for layings is probably considerably more than 100,000 sq.yd (83,600 sq.n sufficient for a stock of up to 5 million oysters. That this is not too high an estimate is suggested by t fact that, in the former fishery in West Loch Tarbert, the laying at Rhu alone held about one milli oysters.

The Fauna

It is useful to compare the bottom fauna of West Loch Tarbert with that of established oyster groun A preliminary qualitative survey on transects of the loch was made in 1955 by Mr. B. T. Hepper, usin Robertson mud bucket and a small oyster dredge. In 1955 and 1956 quantitative sampling was carri out using a Van Veen grab. Table XX gives the 1955 results but only for the main groups of anim and the commonest species. Of the four grounds examined Rhu and Torinturk form a pair with simil faunas. The faunas of the two grounds at Eilean da Ghallagain somewhat resemble each other but sh marked quantitative differences in certain species, particularly amongst the polychaetes.

Differences in the faunas correspond to differences in the composition of the substratum. Thus t Eilean da Ghallagain east bed has a higher proportion of large particles than the other grounds, the w

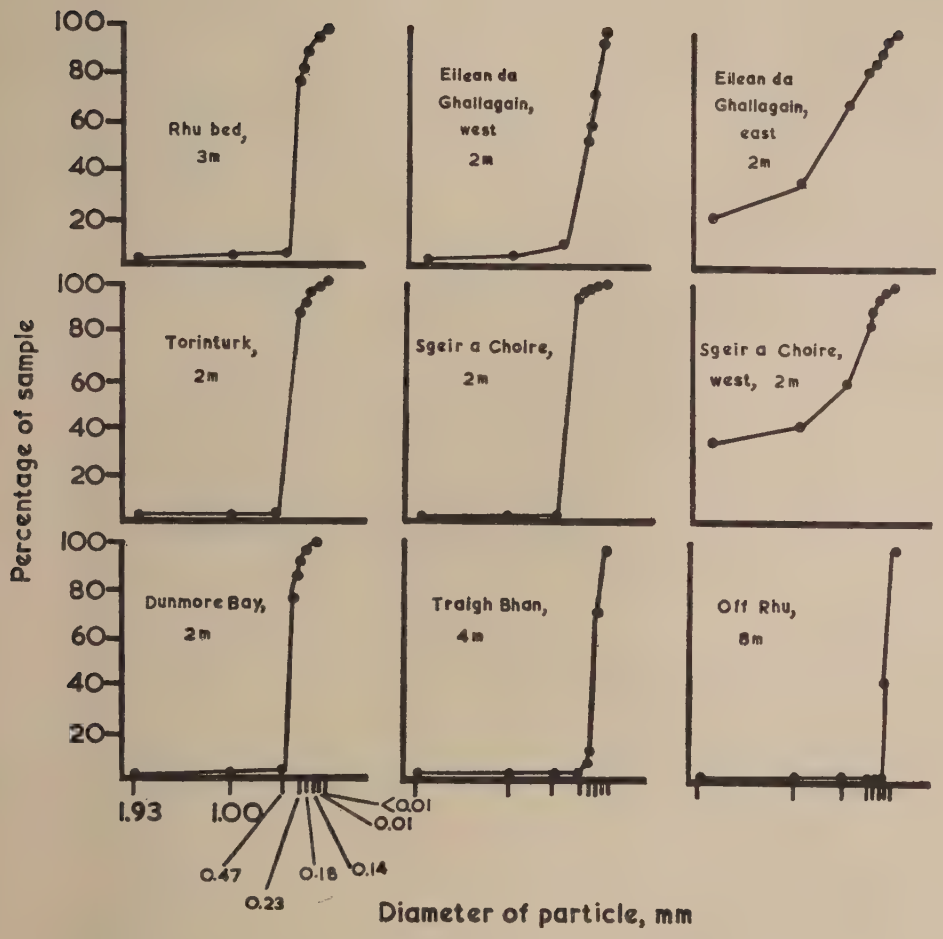


Fig. 32 West Loch Tarbert. Analyses of particle sizes of substratum, shown as cumulative percentages, in different parts of the loch.

bed having the second highest proportion. *Nephthys hombergi* is commonest in the mixture of sand a mud on the Eilean da Ghallagain west bed but is relatively scarce on the coarse substratum of the e bed. The reverse proportions apply to *Melinna palmata*. Amongst the lamellibranchs differences are marked. At Rhu and at Torinturk the substratum, which contains a very small proportion of la particles, is inhabited by a large number of burrowing lamellibranchs. At Torinturk, where the p portion of small particles is greater than at Rhu, *Abra alba,* common at Rhu, becomes scarce; *Tel fabula* is also less numerous at Torinturk, but *T. tenuis* occurs more frequently.

None of these faunistic features can be expected to affect oysters laid on the various grounds, but t might serve to indicate conditions of substratum and water movements associated with better or w growth and fattening of the oysters. Thus, slightly better growth was recorded at Torinturk and R than on either of the beds at Eilean da Ghallagain.

Studies of the bottom fauna of oyster beds have been made by several workers. The composit of the fauna in West Loch Tarbert appears to be intermediate between the faunas of the Heligoland b (Caspers, 1950) and the Essex beds (Mistakidis, 1951). The Heligoland beds are characteristic of a tr marine environment with a firm substratum and the Essex beds of a sheltered environment with a m muddy substratum.

TABLE XX

RESULTS OF QUANTITATIVE FAUNISTIC SURVEY IN WEST LOCH TARBERT IN 1955

Species	No. of specimens per 2 sq.m sample taken by Van Veen grab			
	Rhu	Eilean da Ghallagain, East	Eilean da Ghallagain, West	Torinturk
Nephthys hombergi Lamarck	64	7	265	28
Melinna palmata Grube	1	654	43	9
Clymene oerstedii Claparède	0	208	69	0
Scoloplos armiger (Müller)	0	240	116	6
Bathyporeia guilliamsoniana (Bate)	0	0	0	1
Ampelisca brevicornis (A. Costa)	0	0	3	4
Ampelisca tenuicornis Lillj.	0	4	1	1
Mysella bidentata (Montagu)	41	0	9	57
Venus striatula da Costa	14	1	1	14
Spisula subtruncata (da Costa)	0	0	0	1
Abra nitida (Müller)	0	0	2	5
Abra alba (Wood)	56	12	5	6
Tellina fabula Gmelin	1,033	0	0	384
Tellina tenuis da Costa	18	0	0	286
Phaxas pellucidus (Pennant)	1	0	0	0
Thracia phaseolina (Lamarck)	362	0	0	271
Psammechinus miliaris (Gmelin)	4	13	5	0
Asterias rubens L.	2	2	0	0

Enemies

Three species occurring in West Loch Tarbert are of major importance to a potential oyster fish namely *Arenicola marina* L., *Ascidiella aspersa* (Müller) and *Asterias rubens* L. Of these three only *A. ru* is a predator. *A. marina* is important only in so far as it renders the substratum unsuitable for rela oysters (p. 58). *A. aspersa,* when sufficiently abundant, competes for settling space with oyster larvae can overgrow and smother spat owing to its greater growth rate. In West Loch Tarbert *A. asper* common and during the summer its larvae settle freely on collectors hung in the water. However, in certain parts of the loch, particularly on the Eilean da Ghallagain west bed do they settle abunda on bottom culch and on living oysters. On the Rhu bed and in areas nearer the mouth of the loch se ment on bottom material is sparse. This competitor does not, therefore, present a serious problem.

A. rubens is the most dangerous enemy of adult oysters in the area. Its destructive ability is show experiments on the Rhu beds in 1955. Two similar cages of fine-meshed wire netting, 1 m square

pletely closed, were placed on the bottom. One cage contained 100 oysters and 5 *A. rubens*, and the r cage, arranged as a control, contained 100 oysters but no starfish. The cages were examined every days and after 38 days 54 dead oysters were found in the experimental cage and only 4 in the control. revealed a mortality due to one starfish of about one oyster every four days.

The number of starfish on the Rhu beds was estimated in three ways: (1) using a glass bottomed ing box at low water, visual counts were made of the number of starfish within a metal frame, 1 m re, dropped at random on the beds; (2) using the same frame, a free swimming diver counted starfish; stimates were made from the samples taken by a Van Veen grab. The results obtained by the three ods are given in Table XXI. Counts ranging from 0·25 to 1·0 per sq.m may be compared with figures ned from Essex beds by Mistakidis (1951) of 1·0 per sq.m and from German beds by Hagmeier . Kändler (1927) of 1·1 to 4·0 per sq.m.

Table XXI

DENSITY OF *Asterias rubens* ON RHU BEDS, WEST LOCH TARBERT, AS ESTIMATED BY DIFFERENT METHODS

Method of estimation	Date	Total area examined (sq.m)	No. of *A. rubens* per sq.m
Visual counts from boat	11.7.55	50	0·28
	6.8.56	20	0·25
Diver	18.8.57	21	0·33
Van Veen grab	7.9.55	2	1·0
	28.8.56	2	1·0

Measurements of starfish on the Rhu grounds on 5th May, 1955, show that 34% were over 6 cm in eter across the rays; only starfish of this size should be able to destroy oysters of 4 cm diameter. ller starfish would be able to open spat and half-grown oysters. Hancock (1955) found that on Essex *A. rubens* prefers mussels and *Crepidula fornicata* (L.) to oysters. On the Tarbert beds, however, it eats rs since the other two species are absent.

It is the regular practice in most commercial oyster fisheries to remove and destroy starfish, various ods being used. In the former fishery in West Loch Tarbert baited traps were employed (p. 11). ng the present investigation starfish were dealt with in three ways:

(1) All starfish caught in the dredge were taken ashore. The numbers destroyed in this way were not counted, but must have been considerable.

(2) Baited traps were set and hauled at intervals. Various kinds of bait were used, but mainly salt herring. The effectiveness of this method may be judged by the results obtained by Captain R. Walker, who caught 476 starfish in 13 days using two traps. The advantage of this method lies in the ease with which traps are worked and in the time saved by leaving them on the ground while other work is in progress.

(3) Divers were employed through the co-operation of the Dundee Sub-aqua Club. In one trial three divers removed 298 starfish from the Rhu beds in 1½ hours. Perhaps the greatest advantage of this method is its effectiveness and the certainty that ground has been cleared of large individuals.

By these methods the starfish on the ground may be prevented from seriously depleting the stock of ers.

Loosanoff and Shipley (1947) concluded that the American starfish *Asterias forbesi* (Desor) locates ood accidentally in the course of random wanderings rather than by sense of smell. However, the ess with baited traps in West Loch Tarbert has raised the question whether *A. rubens* might not ct the bait from a distance. Accordingly, experiments were made with two similar traps only one

of which contained bait. The salt herring bait was suspended in the centre of a cage of fine-mesh netting out of reach of the starfish. In 45 trials the baited trap caught 51 starfish and the unbaited c 5 starfish. Statistically this is significant ($\frac{d}{\sigma d} = 3 \cdot 7$) and the conclusion is that in these experiments t starfish detected their food without having touched it. It may be, of course, that they can detect it or from a short distance and that, having come to the trap by accident, they located the bait and remain Starfish accidentally reaching the unbaited trap, however, would continue their random wanderin For practical purposes the effectiveness of bait is undoubted.

Breeding of oysters

A small preliminary laying of oysters was made in April, 1953, and by October these oysters h grown well and were in satisfactory condition (p. 70). However, growth and fattening might be sa factory but breeding insufficient; it was therefore decided to study the breeding of introduced oyste

On 29th April, 1955, 150,000 French two-years-old oysters were laid. To make good losses and increase the breeding stock this was followed by the laying of 50,000 three-years-old oysters in 1956, a of 14,000 of the same age in 1957. These layings were made at Rhu and on the east and west sites ne Eilean da Ghallagain. Samples of adult oysters were examined at intervals during the summer to find t proportions which were carrying larvae. Females with young embryos are classified as whitesick a those with advanced embryos as blacksick. Thirty to fifty oysters were examined in each sample t results of which are given in Table XXII. These figures may be compared with Korringa's (1940) recor for French oysters relaid in the Dutch Oosterschelde (Table XXIII).

TABLE XXII

PERCENTAGE OF WHITESICK AND BLACKSICK FEMALE OYSTERS IN SAMPLES FROM WEST LOCH TARBERT IN 1955, 1956 AND 1957

Date	7·7·55	12.7·55	25·7·55	9·8·55	18.8.55	29.8.55	5·9·55	31.7.56	6.8.56	27.8.56	4·9·56	3·7·57	17·7·57	31·7·57	12.8.57	17·9
Percentage whitesick	7·2	11·4	2·8	2·0	3·1	7·1	0	37·0	12·0	3·0	10·0	20·0	11·4	8·6	0	
Percentage blacksick	1·8	2·8	5·6	2·0	0	0	0	3·0	21·0	9·0	10·0	2·8	0	0	0	12
Total percentage with larvae	9·0	14·2	8·4	4·0	3·1	7·1	0	40·0	33·0	12·0	20·0	22·8	11·4	8·6	0	12
No. of oysters examined	50	35	35	50	31	28	35	40	33	34	40	35	35	35	35	39

TABLE XXIII

PERCENTAGE OF WHITESICK AND BLACKSICK FEMALE OYSTERS FROM THE DUTCH OOSTERSCHELDE (KORRINGA, 1940)

	Date	20.6.39	12.7.39	2.8.39	No. of oysters examined
Percentage whitesick	French 1938 stock	6·0	4·0	20·0	50
	French 1939 stock	14·0	4·0	16·0	50
Percentage blacksick	French 1938 stock	8·0	0	0	50
	French 1939 stock	4·0	0	8·0	50
Total percentage with larvae	French 1938 stock	14·0	4·0	20·0	50
	French 1939 stock	18·0	4·0	24·0	50

It is evident that a satisfactory proportion of the French oysters laid in West Loch Tarbert produced
ıe. The percentage of females with larvae in 1955 was much lower than in 1956; in 1957 the percent-
vas somewhat lower than in 1956. It seems likely that the embryos were incubated for a shorter time
liberated more quickly in the higher temperatures of 1955 than in either of the other years. The high
bers of incubating females in 1956 may have resulted from exceptionally slow development of the
ryos at the prevailing low temperatures. In 1957 the greatest percentage of incubating females
rred early in July and may have resulted from the very warm weather in June. The early spawning
)57 evidently allowed time for a second incubation period in September.

The number of larvae produced by a single female has been estimated by several workers (Dantan,
; Cole, 1941; Cerruti, 1941). In British waters the numbers seem to vary from about 90,000 for a
year-old oyster to over a million for an oyster of 4 years of age. The numbers of larvae were estimated
ur French oysters relaid in West Loch Tarbert in 1955 as two-years-old oysters. At the time of sampling
oysters were about four-years-old. Details are given in Table XXIV.

TABLE XXIV

NO. OF LARVAE PRODUCED BY 4-YEARS-OLD FRENCH OYSTERS IN WEST LOCH TARBERT

Diameters of oysters (cm)	No. of larvae in oyster, as estimated from 5 sub-samples					Mean No. of larvae in oyster
7·3 6·2	698,000	711,000	752,000	732,000	774,000	733,400
7·3 7·4	1,610,000	2,050,000	1,363,000	1,376,000	1,319,000	1,543,000
7·4 7·6	1,189,000	1,241,000	1,123,000	1,079,000	1.143,000	1,155,000
8·5 8·3	530,000	624,000	618,000	586,000	622,000	616,000

These estimates agree with Cole's and indicate that the French oysters, after about one year in West
Tarbert, were producing as many larvae as native oysters of the same size on English beds.

ımbers and growth of larvae

Quantitative plankton samples were taken at intervals of a few days throughout each summer.
results for 1955 and 1956 are shown in Table XXV; no records are given for 1957 owing to the
ity of larvae in that year. The concentration of larvae was generally between one and ten per 100
of water, except in 1957 when numbers were much lower. The figures may be compared with those
)utch waters (Korringa, 1940) and for Essex waters (Knight-Jones, 1952; Waugh, 1957). In each
ese areas the larvae often numbered a few hundreds per 100 litres of water; in Essex the number
ionally reached 1000. The density in West Loch Tarbert was, therefore, about 1/100th of that in
Oosterschelde and in Essex, but the stock of breeding oysters in West Loch Tarbert was small in
ion to the volume of water and the number of larvae would naturally be correspondingly small.
average stock during the three years cannot have much exceeded 100,000 whereas several million
rs were present on the Essex beds and up to 36 million in the Oosterschelde. In relation to the much
er breeding stock it seems that the production of larvae in West Loch Tarbert was fairly satisfactory
)t in 1957.

Survival and growth in 1955 and 1956 may be estimated from Table XXV although the rather
numbers make an accurate estimate impossible. In 1955, survival and growth were best in the last
weeks of August, a small number of eyed larvae being present in the samples during most of that
d. In 1956 eyed larvae were seen only once, on 1st August. In 1957 both production and growth
very poor, no eyed larvae having been found at any time; the greatest density was 15 larvae per
litres on 27th August.

Table XXV

WEST LOCH TARBERT; NUMBER PER 1,000 LITRES AND SIZE OF OYSTER LARVAE IN 1955 and 1956. ALL SAMPLES TAKEN BY PUMP (E DENOTES EYED LARVAE)

		Percentage distribution by size (mm)														
Date	Position	0·17	0·18	0·19	0·20	0·21	0·22	0·23	0·24	0·25	0·26	0·27	0·28	0·29	Depth (m)	No. of larvae p 1,000 litr
14.7.55	Eilean da Ghallagain		33	66											–	7·5
16.7.55	Rhu	3	50	21	26										–	85
18.7.55	Eilean da Ghallagain		33	0	66										–	7
22.7.55	Eilean da Ghallagain	5	15	10	45	10	10	0	5						–	50
25.7.55	Eilean da Ghallagain			16	34	34	16								0·5	15
				25	50	0	25								4·0	5
28.7.55	Rhu		52	28	20										2·0	52
2.8.55	Eilean da Ghallagain		12	27	36	3	17	5							1·5	70
6.8.55	Rhu				66	33									1·5	5
8.8.55	Eilean da Ghallagain	14	14	14	58										0·5	17
		4	22	16	34	16	8								2·0	60
10.8.55	Eilean da Ghallagain		15	24	34	15	8	2	2						0·5	160
			24	24	24	10	14	4							1·0	50
			51	12	25	0	0	0	0	0	12				2·0	20
			46	27	27										3·0	27
			6	19	19	6	19	6	6	6	13 (6% E)				4·0	40
11.8.55	Eilean da Ghallagain			5	48	5	27	10	5						2·0	50
15.8.55	Escart		52	20	28										0·5	62
			38	22	33	0	4·6	2·4							1·0	110
		1·5	31	40	26	0	0	0	1·5						2·0	160
			26	48	26										3·0	80
			31	31	35	1·5	1·5								4·0	140
22.8.55	Escart	2	4	4	21	8	17	17	15 (2% E)	6 (2% E)	6 (2% E)				0·5	120
		4	12	12	26	9	9	9	9	4	6 (4% E)				3·0	110
23.8.55	Eilean da Ghallagain			5	27	10	23	15	10	0	10E				2·0	50

TABLE XXV (Contd.)

Position	Percentage distribution by size (mm)												Depth (m)	No. of larvae per 1,000 litres
	0·17	0·18	0·19	0·20	0·21	0·22	0·23	0·24	0·25	0·26	0·27	0·28	0·29	
Eilean da Ghallagain		34	22	0	0	22	11	11						0·5	20
	7	0	25	27	27	0	0	0	7	0	7E			3·0	40
Escart	17	33	0	17	0	33								0·5	15
		100												3·0	5
Escart		21	21	30	10	14	2	2E						0·5	120
	8	16	8	27	8	17	8	0	0	8E				3·0	30
Escart			67	33										0·5	7
	12	18	12	28	12	6	6	6						3·0	40
Escart			18	50	27	5								2·0	55
Eilean da Ghallagain				33	33	0	0	33						2·0	7·5
Eilean da Ghallagain		18	18	52	8	0	4							2·0	70
Eilean da Ghallagain			33	66										0·5	7·5
		8	16	51	25									2·0	30
Escart		10	35	35	0	10	0	10						3·0	22
Eilean da Ghallagain				50	0	25	0	0	0	0	0	25E		1·0	1
				50	25	25								3·0	10
Eilean da Ghallagain				33	33	0	33							3·0	7·5
Escart		33	33	33										1·0	12·5
		28	44	28										3·0	17·5
Rhu		7	28	65										2·0	35
Rhu		14	44	44										2·0	17
Rhu	21	42	37											2·0	317
Escart			100											2·0	5
Rhu			66	33										2·0	7·5
Rhu		33	33	23	11									2·0	22
Rhu	12	53	27	4	4									2·0	65
Escart		20	80											2·0	12

The periods of better larval growth in 1955 and 1956 coincided with somewhat higher numbers small flagellates, a result in agreement with the findings of Knight-Jones (1952) and Waugh (195 but the evidence of this correlation in West Loch Tarbert was not strong.

Dispersal of larvae

Large water movements could possibly remove larvae from the loch before they have time to gr and settle. In order to study this dispersal large numbers of newly liberated larvae were stained w neutral red and the subsequent movements of the living larvae followed by sampling the plank according to the method described by Loosanoff and Davis (1947). The results are shown in Table XX and the stations in Fig. 29. Dispersal at the rate indicated in these two experiments would scatter t larvae throughout the length of the loch during the period of their pelagic life, unless they behave such a way as to remain in the upper parts of the loch. There is, however, no evidence of any su behaviour.

Table XXVI

NO. OF STAINED OYSTER LARVAE RECOVERED IN DISPERSAL EXPERIMENTS IN WEST LOCH TARBERT

Experiment No.	Point of release	Time between release and recovery (h)	No. of stained larvae recovered per sample of 340 l.									
			St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10
1	Rhu beds	18	5	1	7	5	7	13	0	3	6	1
2	Rhu Point	12	0	9	0	8	3	1	0	24	0	0

Nanoplankton

Measurements of the concentration of flagellates available as food for the larvae were made counts using a Thoma haemacytometer and dark ground illumination (p. 43). The concentrations flagellates under 10 μ in diameter, in samples taken during 1955 and 1956, are shown in Table XXV

Table XXVII

CONCENTRATIONS OF FLAGELLATES UNDER 10μ IN DIAMETER IN WEST LOCH TARBERT

Date	4.7.55	22.7.55	28.7.55	2.8.55	4.8.55	6.8.55	8.8.55	12.8.55	23.8.55	25.8.55	26.8.55	29.8.55	31.8.55
No. of flagellates per cu. mm	1·0	0·5	0·7	0·6	0·4	2·0	1·0	1·3	1·3	0·8	1·3	2·0	1·2

Date	23.7.56	26.7.56	30.7.56	1.8.56	3.8.56	7.8.56	15.8.56
No. of flagellates per cu. mm	0·4	1·2	1·1	1·7	1·5	0·5	0·3

These numbers, in most samples between 0·5 and 2·0 per cu.mm, are considerably lower than th generally present in the waters of the Essex beds, where Waugh (1957) recorded densities gener about 5 per cu.mm and sometimes rising to 10 per cu.mm. Although, as already suggested, there perhaps some evidence of better larval growth during periods of higher densities of nanoplankton West Loch Tarbert, the value of such observations is doubtful owing to the difficulty of identify organisms of the nanoplankton in the field.

patfall

It is difficult to find newly settled spat, particularly if they are few and widely scattered, as they were West Loch Tarbert where the breeding stock was relatively small. After a few months, however, spat more readily seen and it is then simpler to determine if a spatfall has occurred. Examination of ls from 16th to 19th September, 1955, showed a small number of spat amounting to only a few to ry 40 to 50 shells. This spatfall resulted from the presence of eyed larvae in the water during the ond half of August. No settlement was detected during the summer of 1956, but some months later w spat of that season were found. The spatfall was lighter than that of 1955. There was apparently spatfall in 1957.

Mortality of adults

The natural mortality was estimated from counts of pairs of empty shells and of living oysters in dged samples. Table XXVIII shows the percentage of dead oysters in samples of those laid at Rhu 13th May, 1955. The total mortality on this ground in 26 months was 34·9%. It is impossible to break vn this figure into fractions each assigned to a different cause, although no doubt death was caused various factors. The fact that more than one third of the total mortality over the whole period occurred hin the first six weeks after the oysters were laid strongly suggests that much of this fraction resulted n the harmful effects of transporting the oysters from France. The mean size of all the dead shells a sample taken on 5th September, 1955, was 5·08 cm. This size corresponds on the growth curve to e 1955, thus providing further confirmation of early deaths.

Table XXVIII

MORTALITY IN FRENCH OYSTERS LAID ON 13TH MAY, 1955, AT RHU, WEST LOCH TARBERT

Date of sample	25.7.55	17.8.55	5.9.55	20.7.56	31.7.57
Percentage dead in sample	13·7	15·1	15·4	34·6	34·9

Evidence from experiments with starfish (p. 61) and examination of dead shells suggest that an portant further cause of loss was attack by starfish. As Hancock (1955) has shown, oysters killed in way have a characteristic appearance. A remarkable and unexplained increase in deaths occurred ing the period from September 1955 to July 1956. Whether this was largely a winter mortality is known. The figures in Table XXIX for mortality on the Eilean da Ghallagain west bed are rather consistent, but show the same order of mortality as on the Rhu beds.

Table XXIX

MORTALITY IN FRENCH OYSTERS LAID ON 13TH MAY, 1955, AT EILEAN DA GHALLAGAIN WEST, WEST LOCH TARBERT

Date of sample	12.7.55	21.7.55	24.8.56	3.7.57	12.8.57
Percentage dead in sample	16·1	18·6	34·0	25·0	30·0

Growth

The growth rate is shown in Fig. 9, which gives the mean antero-posterior diameter of oysters from beds at Rhu, Eilean da Ghallagain west, Eilean da Ghallagain east and Torinturk. A favourable ure of the results is the continued growth of the oysters, at a fairly high rate, into their third year after

laying. It appears that the Eilean da Ghallagain west ground gives a slightly lower growth rate than the Rhu ground. The oysters transferred to the Torinturk ground at first grew faster than those left at Rhu but subsequently grew less quickly, and by the middle of 1957 no difference was observed in the mean size. Oysters grew more slowly on the Eilean da Ghallagain east laying than on any of the other grounds, but even here growth was fairly satisfactory.

Fattening

Fatness was in all cases measured by the condition factor. Fig. 33 shows the results obtained from the preliminary laying in West Loch Tarbert in 1953. The oysters were fat from September to February after which the condition factor decreased to a relatively low value in March. This decline was apparent in each year. From March to May the factor rose as a result of increased feeding, and dropped sharply after spawning in the summer. The important period of fattening in August and September is indicated by the rising condition factor at that time. Table XXX shows the percentage of oysters in different grades of condition in each of the samples taken throughout the winter, i.e. the season when the stock would be sold and, therefore, when condition is most important. The results of the preliminary laying in 1953 and the main laying in 1955 are included. Oysters in the ratings moderate, satisfactory and very satisfactory are generally acceptable on the market. It will be seen that these three grades together contain from 60 to 95% of the oysters. The mean is 79% which represents a favourable proportion of the oysters of marketable size. It may therefore be said that West Loch Tarbert is a good fattening area.

The value of West Loch Tarbert

The physical conditions, temperature, salinity and water movements have all been found favourable to breeding. The large volume of water in the loch demands a large breeding stock of oysters if substantial spatfalls are to be secured. One fishery with a stock of a few million oysters, or several fisheries of moderate size, would, however, provide an adequate breeding stock. One of the most important biological conditions is the supply of larval food. The apparent scarcity of the right kinds of flagellates may be a factor which limits the amount of spatfall in this area. Another factor having the same effect is the shortage of culch on the bottom. At present most of the material on which larvae settle consists of the shells of oysters which have been introduced. If a fishery were started, however, this deficiency would be made good, partly by the introduction of a much greater stock of adult oysters and partly by the laying of culch in the form of shell. Artificial collectors could also be used, but this in the absence of a high concentration of larvae in the water is a more costly way of securing increased spatfalls. All the available evidence suggests that breeding is likely to be satisfactory once in every two or three years provided that the ground is well stocked, supplied with culch and properly cultivated. This should provide a fairly sound basis for a fishery. A fishery depending on the regular importation of young stock would have good prospects as the experiments have consistently shown satisfactory growth and fattening. Mortality in the relaid stock, which would appear to be due largely to starfish, could be reduced by the removal of this predator. This would not present a serious problem to anyone working the fishery on a commercial scale. These facts, together with the proximity of Tarbert to markets show that West Loch Tarbert is one of the more suitable areas investigated.

CONCLUSIONS

The Scottish oyster research programme has not been exhaustive, but it has dealt with the main practical problems in a sufficient variety of places to permit an assessment of the prospects of reviving former fisheries or of starting new ones. Social and economic factors would obviously be important in any commercial venture, but the aim of the research programme has been to provide purely technical solutions to the various problems involved.

Table XXX

CONDITION FACTOR OF OYSTERS FROM WEST LOCH TARBERT SAMPLED DURING THE MARKETING SEASON—YEAR AND PLACE OF LAYING AND DATE OF SAMPLING ARE SHOWN FOR EACH SAMPLE (FOR BREVITY EILEAN DA GHALLAGAIN IS REFERRED TO AS ISLAND)

Condition factor	Market rating	Percentage of sample														
		Year laid: 1953	1953	1953	1953	1953	1953	1953	1955	1955	1955	1955	1955	1955	1955	1955
		Place Island	Island	Island	Island	Island	Island	Island	Rhu	Island	Rhu	Rhu	Torinturk	Island	Rhu	Rhu
		Date sampled: 9.10.53	2.3.54	23.9.54	10.12.54	23.2.55	25.3.55	28.2.56	5.9.55	29.2.56	28.4.56	4.9.56	4.9.56	13.3.58	13.3.58	28.10.58
0·30—0·34	Very unsatisfactory	5	0	5	0	5	0	0	5	0	0	0	5	0	0	5
0·35—0·39	Unsatisfactory	0	15	5	5	10	15	10	5	0	0	10	5	10	10	0
0·40—0·44	Poor	5	20	0	25	10	20	10	10	25	5	10	0	30	10	15
0·45—0·49	Moderate	30	20	25	15	25	40	40	35	35	15	35	15	40	50	25
0·50—0·54	Satisfactory	50 } 90	40 } 65	10 } 90	30 } 70	20 } 75	15 } 60	10 } 80	25 } 80	25 } 75	35 } 95	10 } 80	20 } 90	20 } 60	20 } 80	25 } 80
Over 0·54	Very satisfactory	10	5	55	25	30	5	30	20	15	45	35	55	0	10	30

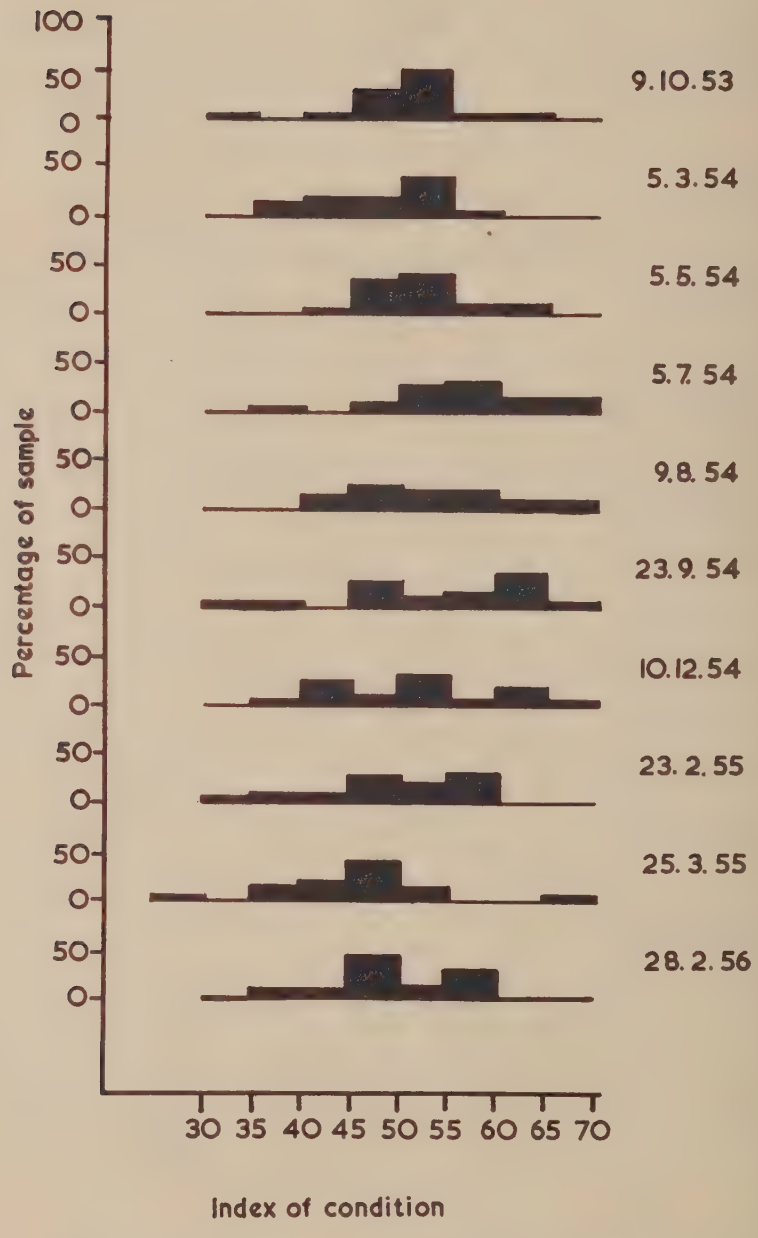


Fig. 33 West Loch Tarbert oysters. Percentage distribution of condition factor.

Several areas have proved satisfactory for growing relaid French oysters and there is little doubt ıt further surveys and experiments would reveal others just as suitable. The satisfactory areas, compared ıh the Essex beds, have on the whole rather slower growth but fattening is as good and in some cases ter. Results are, therefore, similar to those on proved commercial beds and the final product is accept-le on the market.

Fewer places have the conditions necessary for breeding but some are suitable, notably Loch Ryan, ınne Mhuirich in Loch Sween, probably Little Loch Roag and, with reservations, West Loch Tarbert.

The best areas are those that promote breeding as well as growth and fattening. Of all the sites ımined, Loch Ryan appears to meet both requirements most satisfactorily, although experiments re are still at an early stage.

Breeding is also fairly satisfactory in Linne Mhuirich although the area available for laying is much s than in Loch Ryan. In Little Loch Roag, breeding has maintained a population of oysters and the a might well support a fishery. West Loch Tarbert would probably support a self-maintaining fishery ı sufficiently large breeding stock were introduced.

In other places, however, where breeding is insufficient, two solutions to the problem of recruiting ung stock to replace losses in older stock from marketing and natural mortality appear possible. Young sters may either be imported or bred artificially for relaying. The former course is in fact common actice for restocking commercial beds. Although the second possibility has not yet been developed as practical alternative, controlled breeding under laboratory conditions would appear to have an portant bearing on the future of commercial fisheries. An oyster hatchery, in addition to producing ıt independently of seasonal conditions, would have other advantages. Strains of oysters adapted to ottish conditions could be selected and rapidly increased. This would improve the stock and remove danger of introducing disease and pests with imported oysters. An important part of the research ogramme, to be described in a later publication, has therefore been concerned with the production of ıt, either in large concrete tanks according to the methods of Cole (1937, 1938, 1939) or by the hniques developed by Loosanoff (1945) and Loosanoff and Davis (1950) in the U.S.A. and by Walne 56a, 1956b) in Wales.

Perhaps the main disadvantages of many of the Scottish sites are their remoteness and the consequent h cost of transport, whether of young stock to the beds or of old stock to market. Nevertheless, many the Scottish sites have certain advantages over the established English beds, for example, in their edom from pollution and from imported pests and enemies such as the American *Crepidula fornicata* and *Urosalpinx cinerea* (Say). It is important that these pests should be excluded from Scottish waters d for this reason oysters should not be brought from English beds.

The observations and experiments reported in this account encourage the belief that, with careful ection of proved sites, proper management, cultivation, conservation and assistance from fishery entists it should be possible to establish sound commercial oyster fisheries in Scotland.

SUMMARY

Prehistoric and historic evidence shows that oysters were formerly common in a number of places ınd the Scottish coast. In most of these places oysters are now much scarcer than formerly and are ent from some areas where they were abundant.

There is evidence that overfishing has been the main cause of the decline or local extermination stocks.

A brief history is given of the Scottish oyster fisheries.

In the Firth of Forth and Loch Ryan, where the largest fisheries existed, physical conditions do not m to have changed significantly. It would be difficult to re-establish a fishery in the Firth of Forth. ch Ryan is, however, a favourable site for reviving a profitable fishery, and recommendations are made.

Field experiments on growing and fattening relaid oysters are described.

Field experiments on breeding, in Linne Mhuirich (Loch Sween), at Easdale, and in West Loch rbert are described.

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APPENDIX

CONDITION OF OYSTERS IN SAMPLES FROM EXPERIMENTAL LAYINGS

Place of laying	Date of laying	Date of sample	Condition factor, percentage of sample						
			Under 0·35	0·35–0·39	0·40–0·44	0·45–0·49	0·50–0·54	Over 0·54	Total over 0·44
Craignish (Dun Mhuilig)	1950	11.11.50	0	0	18	46	28	8	82
	1950	24. 3.51	7	14	43	29	7	0	35
	1950	1.11.51	0	0	20	10	20	50	80
	1950	15. 2.53	10	0	0	0	80	10	90
	mixed origin	6. 3.54	5	10	25	15	25	20	60
	mixed origin	14. 9.54	5	0	5	10	15	65	90
	1954	17. 9.55	0	10	10	10	20	50	80
	1954	6. 9.56	0	10	10	30	25	25	80
	1955	27. 2.56	0	10	15	25	30	20	75
	1955	16. 3.57	5	5	30	25	15	20	60
Craignish (mud flats)	1954	27. 2.56	5	10	10	35	5	35	75
t Loch Tarbert (Leamnamuic)	1956	20. 9.58	15	20	15	15	10	5	30
Gair	1955	5.11.56	0	5	10	25	35	25	85
	1957	22.10.57	0	5	35	15	40	5	60
	1957	26. 9.58	0	10	15	55	10	10	75
ricar Bay (orth laying)	1949	5. 2.50	10	27	42	5	16	0	21
	1949	23. 3.51	8	42	34	8	8	0	16
	1949	30.10.51	10	0	20	10	40	20	70
	1949	30.10.51	20	20	20	10	20	10	40
	1949	15. 2.53	0	10	0	0	50	40	90
	1949	7. 3.54	0	5	35	20	35	5	60
	1949	15. 9.54	13	5	5	10	27	40	77
	1949	24. 2.55	0	5	5	35	15	40	90
	1949	5. 9.56	0	0	10	10	20	60	90
ricar Bay (outh laying)	1954	28. 2.56	30	25	25	5	10	5	20
	1954	5. 9.56	10	25	30	15	10	10	35
	1954	17. 3.57	10	25	45	20	0	0	20
	1954	28. 9.58	5	15	5	25	15	35	75
Creran (Ardnaclach)	1953	23.10.53	0	15	5	30	40	10	80
	1953	28. 2.56	5	5	20	20	20	30	70
Creran (S. Shian Bay)	1956	18. 3.57	0	15	35	35	15	0	50
	1956	6. 3.58	30	10	40	15	5	0	20
	1956	30. 9.58	0	15	15	15	15	40	70
Melfort (L. na Cille)	1951	31.10.51	0	10	20	20	20	30	70
	1951	15. 2.53	20	13	27	7	33	0	40
	1951	14.10.53	20	25	35	10	10	0	20
	1951	14. 9.54	20	10	25	10	20	15	45
Melfort (Fearnach Bay)	1953	8. 4.54	15	35	25	15	5	5	25
	1953	6.11.56	10	10	15	5	40	20	65
Feochan	1951	31.10.51	20	40	40	0	0	0	0
	1951	15. 2.53	13	40	20	20	7	0	27
	1951	27. 2.56	30	15	25	20	10	0	30
Don	1950	13.10.50	75	15	10	0	0	0	0
	1950	30.10.51	45	35	10	10	0	0	10
Striven	1956	2.10.56	5	10	25	45	15	0	60
	1956	15. 4.58	45	40	15	0	0	0	0
chan Channel	1949	30.11.51	50	50	0	0	0	0	0
chan Farm	1949	30.10.51	80	0	20	0	0	0	0

CONDITION OF OYSTERS IN SAMPLES FROM EXPERIMENTAL LAYINGS

Place of laying	Date of laying	Date of sample	Condition factor, percentage of sample						
			Under 0·35	0·35–0·39	0·40–0·44	0·45–0·49	0·50–0·54	Over 0·54	Tot ove 0·4
L. Leurbost	1955	7.10.55	25	30	35	5	5	0	10
	1955	11.11.56	0	15	20	30	45	0	75
	1955	10. 2.58	5	15	15	50	10	5	65
L. Barraglom	1955	7.10.55	5	0	35	40	20	0	60
	1955	11.10.56	10	25	5	35	20	5	60
	1955	15. 3.58	5	25	25	25	20	0	45
	1955	15.11.58	25	20	35	20	0	0	20
L. Erisort	1955	7.10.55	25	15	25	30	5	0	35
	1955	5.11.56	10	15	25	35	5	10	50
	1955	11. 2.58	5	45	40	20	0	0	10
	1955	15.11.58	60	30	10	0	0	0	0
Breasclete Bay	1955	7.10.55	35	25	15	25	0	0	25
	1955	9.11.56	15	45	30	10	0	0	10
Soay	1955	18.10.56	10	40	25	20	5	0	25
	1955	12. 3.58	40	35	10	10	5	0	15
L. Torridon (Ob Mheallaidh)	1957	17.10.58	0	15	30	15	25	15	55
L. Torridon (Dubh Airde Bay)	1954	20.11.56	0	5	35	35	20	5	60
L. Tournaig	1957	17. 9.58	10	10	20	40	5	15	60
Munlochy Bay	1957	15.10.58	5	5	25	40	25	0	65

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